DRAKE'S
REFRIGERATION SERVICE MANUAL

An Instruction and Reference Book Covering

MAINTENANCE, TROUBLE SHOOTING AND REPAIR

DOMESTIC AND COMMERCIAL SYSTEMS

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ENGINEERING TRADE MANUALS

CHICAGO

FREDERICK J. DRAKE & COMPANY

Publishers

Printed in the U.S.A.

FOREWORD

This manual is primarily an instruction book on accepted methods of servicing and repairing electric refrigerators and refrigeration systems. The first six chapters explain the construction and operation of complete systems and of all their parts. The remaining nine chapters consist of information and detailed instructions relating to installation, testing, trouble shooting, adjustment, removal, replacement, and repair. For performing the great majority of service operations directions are given in numbered steps outlining the exact order of procedure.

The instructions are written to apply to general types of equipment rather than to any certain makes and models of refrigeration apparatus. Thus the service procedures become equally useful with whatever systems are being handled. All illustrations have been especially drawn to carry out this idea of universal application. Each picture or diagram shows the chief features found in all devices of a general type or class, and emphasizes the details which are most important from the standpoint of service and repair.

The work covers practically every operation in field service, as performed where the equipment is installed, and also the shop operations which may be performed with the simpler kinds of equipment. It covers domestic types of refrigerators, and, fully as completely, the commercial types in small and medium sizes such as used in markets, milk depots, soda fountains, flower shops and similar establishments, as well as in many air conditioning systems.

Theories and basic principles are explained only where such explanation is essential or is of direct

help in understanding certain service operations and the reasons for preferring one method to others.

Because the positive location of causes for faulty operation is fully as important as the ability to set things right, the chapter on trouble shooting has been made the largest single chapter in the manual. Here is a series of twenty-three tables, each devoted to the causes and remedies for an easily recognized symptom of faulty operation. Each table then is subdivided in accordance with easily identified conditions which may exist, or else in accordance with types of construction. All the tables are cross-referenced within themselves to insure checking all causes which may be contributing to the evident trouble.

Throughout the manual material has been carefully classified to bring together all the facts relating to each design, each construction, and each class of service operations. In addition there is an extensive index with references under all words likely to come to mind when searching for particular items of information. The index forms a time-saving accessory to the trouble shooting plan, since it permits quickly locating the detailed instructions for whatever adjustments, further tests, or repairs may be called for in the tables.

THE PUBLISHERS

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CHAPTER 1

MECHANICAL REFRIGERATION

Hold your hand in a strong breeze, as from an electric fan. Then wet your hand and hold it in the same breeze. While the water is drying away, your hand feels cooler, but the cooling effect disappears with the water. You have felt the cooling effect of evaporation, which is the basic action in all mechanical refrigeration.

Now light a gas burner and adjust the flame so that it is only about a quarter of an inch high. Draw a couple of quarts of tap water, place the pan over the fire for exactly five minutes, then note the temperature of the water. Do not alter the adjustment of the flame, but empty the warmed water and put a pint of fresh water into the same pan. Warm this water for just five minutes over the flame, then compare its temperature with that produced in the two quarts of water.

The quantity of *heat* (or heat energy) must have been the same in both trials; for you used the same flame, the same pan, and the same heating time. Yet the resulting *temperatures* were decidedly different. Thus we learn that heat and temperature are two different things.

Refrigeration is the process of lowering the temperature of substances refrigerated, and of keeping them lower than the temperatures of other nearby things. The temperature is lowered by removing some of the heat (or heat energy) from the substances refrigerated, and is kept low by hindering the entrance of more heat and by removing the extra heat that does get in.

Now for two more experiments. First, immerse

a fairly large piece of metal in a small quantity of hot water. The temperature of the metal goes up and that of the water goes down. The metal gains heat and the water loses heat. Second, warm the piece of metal to a rather high temperature and immerse it in a small quantity of cold water. The temperature of the metal goes down and that of the water goes up. The metal now loses heat and the water gains heat.

Heat always passes from a substance of higher temperature to another of lower temperature, and under no conditions will heat pass directly from lower to higher temperatures. Note the word *directly*, for soon we shall move heat from the inside of a refrigerator, where the temperature is less than 50 degrees, to the outside air, whose temperature is better than 70 degrees—but not directly.

You have seen and felt the effects of the three fundamentals of refrigeration. *1*. Heat is removed, and temperature lowered, by evaporation of a liquid. *2*. Temperature depends not alone on the quantity of heat or heat energy in a substance, but on the quantity of heat in relation to the weight or volume of the substance. *3*. Heat passes directly only from substances of higher temperature to others of lower temperature.

We have been talking about refrigeration, which we naturally associate with cold, yet we have not talked about cold but only about heat. Cold is merely the absence of heat, or the condition of less heat—just as dryness is only the absence of moisture, and as darkness is only the absence of light.

The only time a substance would contain no heat at all would be were its temperature 460 degrees below zero, Fahrenheit. That is the temperature called *absolute zero*. At all higher temperatures there is some heat energy in all substances. Zero,

on the thermometer, isn't really cold—for it is a temperature 460 degrees above that for no heat at all. Even forty below zero is not cold, it just means less heat than at some higher temperature. Henceforth, in talking about refrigeration, we shall forget about cold and talk only about heat in various quantities.

A Refrigeration System.—In any refrigeration system we employ a *refrigerant* which alternately is evaporated from its liquid condition to form a vapor, and condensed so that the vapor returns to the liquid form. The refrigerant is a substance that evaporates rapidly at low temperatures. As the liquid is evaporated it absorbs heat from everything around it, and lowers the temperature. Then the absorbed heat is in the vapor. As the vapor is condensed back to a liquid it loses the absorbed heat. By causing evaporation to take place where temperature is to be lowered, then causing condensation to take place where the discharged heat won't be objectionable, we accomplish refrigeration.

Fig. 1 shows the principal parts of a commonly used refrigeration system. The compressor is a pump which pumps refrigerant vapor out of the evaporator and compresses it into the condenser. The condenser consists of finned tubing, something like that in an automobile radiator, and here the compressed vapor loses heat to the surrounding air and condenses to form drops of liquid refrigerant. The drops, with the remaining vapor, are forced into the receiver where the liquid collects in the bottom.

Pressure maintained in the receiver, by action of the compressor, forces liquid refrigerant through the liquid line tubing to the refrigerant control valve. This valve admits liquid refrigerant to the evaporator, which consists of tubing. The liquid

evaporates to vapor in the evaporator, absorbing heat in the process, and the vapor is drawn through the suction line tubing to the compressor.

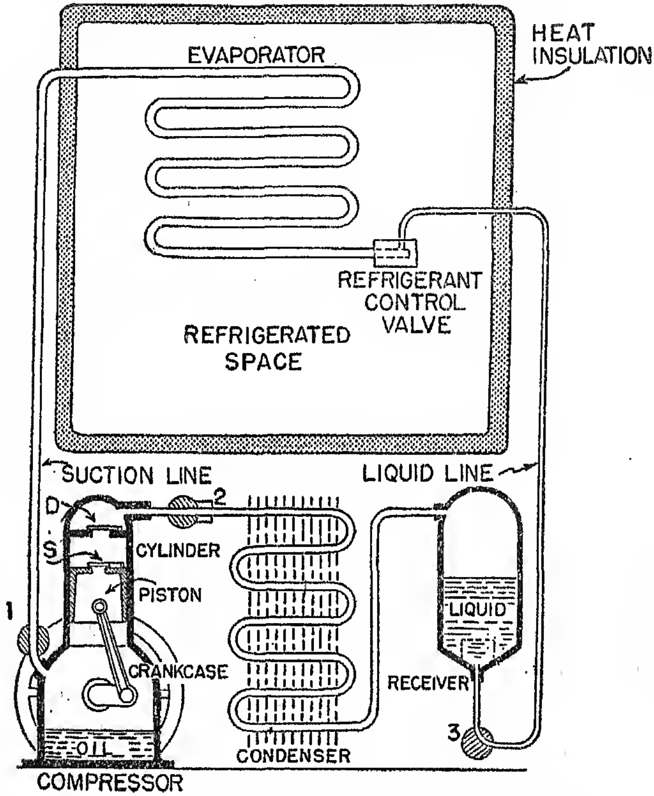

Fig. 1.—The Principal Parts of a Simple Refrigeration System.

In the top of the compressor piston is a suction valve *S*, and in the top of the cylinder is a discharge valve *D*. As these valves move upward against the tension of light springs they open their ports and

permit passage of vapor through them. When the valves move downward they close their ports and prevent passage of vapor. As the piston moves downward in the cylinder, the discharge valve *D* is closed because the pressure above it is greater than the pressure below it, while suction valve *S* is opened because the pressure below it is greater than that above it. Then refrigerant vapor from the compressor crankcase goes through the suction valve into the space between the top of the piston and the partition in which is the discharge valve.

As the piston moves upward in the cylinder, suction valve *S* closes and discharge valve *D* opens.

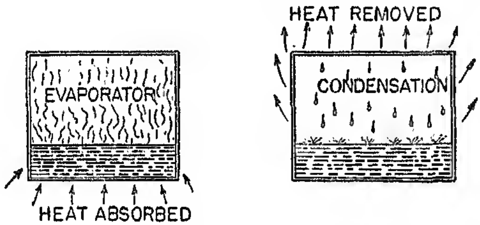

Fig. 2.—Absorption of Heat Causes Evaporation; Removal of Heat Causes Condensation.

Vapor which is trapped above the piston is forced through the discharge valve into the condenser. So the process continues. There is compression, condensation, and loss of heat in the condenser and receiver. There is expansion, evaporation, and pickup of heat in the evaporator.

Valves *1, 2* and *3* are hand-operated *service valves* whose purpose it is to shut off the several parts of the system one from the others when service operations or tests are to be performed.

Evaporation and Condensation.—The preceding brief explanation told only some of the mechanical details of how a space may be refrigerated, but told

nothing of why refrigeration proceeds as it does. To really understand refrigeration we must become acquainted, first of all, with the relations between evaporation, condensation, temperature and pressure in a closed space containing the liquid and vapor of a refrigerant.

To begin with, we cannot have evaporation of any liquid into its vapor unless heat is added to the liquid or unless the liquid absorbs heat. This is illustrated in Fig. 2. Furthermore, it is impossible for a vapor to condense into its liquid unless heat is extracted from the vapor or unless the vapor loses heat, as also illustrated in Fig. 2.

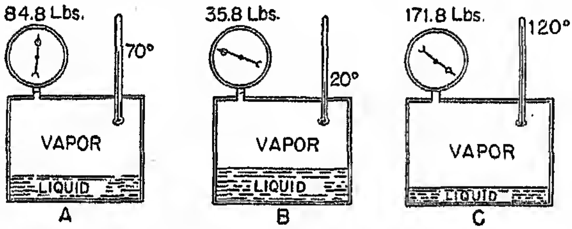

Fig. 3.—Vapor Pressures Change with Changes of Temperature.

Temperatures and Pressures.—Now, as in Fig. 3, we shall put some of the refrigerant called Freon-12 into a closed tank which is equipped with a gage for measuring pressures of the vapor, in pounds per square inch, and with a thermometer for measuring the temperature of the vapor in Fahrenheit degrees.

With the tank tightly closed we shall place it in a room where the temperature is 70 degrees and leave it there until the thermometer on the tank shows that the vapor temperature has become just 70 degrees. The pressure gage will read 84.8 pounds. Then we shall place the tank where the

temperature is only 20 degrees above zero. When the thermometer shows that the vapor temperature is 20 degrees the gage will show that the vapor pressure has dropped to 35.8 pounds. Finally, with the tank in a place where the temperature is 120 degrees, the gage will read a vapor pressure of 171.8 pounds when the vapor temperature becomes 120 degrees.*

When a liquid and its vapor are in a closed space, for every temperature of the vapor there is an exact corresponding pressure. You cannot get away from this fixed pressure-temperature relation for the liquid you are using. If you change the temperature the pressure will soon change to correspond, and if you change the pressure the temperature will soon follow along.

Why did the vapor pressure decrease when the temperature was reduced between *A* and *B* of Fig. 3? Because, at the lowered temperature the vapor lost some of its original heat, some of the vapor condensed to liquid, and the remaining smaller concentration or density of vapor produced lower pressure. The pressure exerted by a vapor in a closed space always corresponds to the density or to the concentration of the vapor, which means the weight of vapor per cubic foot of space.

Why the vapor pressure increased between *B* and *C* of Fig. 3 now is easily answered. The vapor pressure increased because at the higher temperature the liquid absorbed heat, and this heat caused some of the liquid to evaporate into vapor. Then the greater vapor density produced more pressure in the space.

Instead of changing the temperature let's change the pressure inside the tank of refrigerant vapor

*These pressures are absolute pressures. Pressure units and measurements will be explained later.

and liquid, as in Fig. 4. Here we have attached a pump, and have pumped vapor out of the tank until the internal pressure or vapor pressure falls to 35.8 pounds. Assuming that the vapor and liquid originally were at the temperature of the surrounding air, 70 degrees, we now have inside the tank a pressure far below that which normally corresponds to a 70-degree temperature.

In an attempt to bring the vapor pressure up to the value corresponding to 70 degrees of temperature the liquid immediately commences to evaporate at a great rate. But we cannot have evaporation of a liquid without absorption of heat by the liquid, so the liquid commences to absorb heat from everything around it. As heat is absorbed, the temperature falls lower and lower. The pump keeps pulling out vapor to hold the pressure down to 35.8 pounds. Finally, when everything in and around the tank gets down to a temperature of 20 degrees, evaporation stops; for then we have the 20-degree vapor temperature that corresponds to a vapor pressure of 35.8 pounds with Freon-12 as the refrigerant.

Here we have observed in action the rule that heat always flows from a higher to a lower temperature. The first heat for evaporation came from the 70-degree liquid inside the tank. This happened just as soon as the vapor pressure dropped below the value corresponding to 70 degrees of temperature. Loss of heat lowered the temperature of the liquid, after which heat continued to flow from the warmer surrounding air through the evaporator tubing into the cooler liquid.

Next, as in Fig. 5, we shall connect the pump to the tank in such manner as to raise the vapor pressure inside the tank. Assume that we commence this operation with the contained vapor and liquid at the 70-degree temperature of the surrounding

air. As soon as the vapor pressure rises we have a vapor pressure too high for the temperature. But, along with the vapor being pumped into the tank, we are pumping in the heat contained in that vapor, so the vapor temperature inside the tank commences to go up.

With higher temperature in the tank than in the surrounding air, heat commences to flow from the

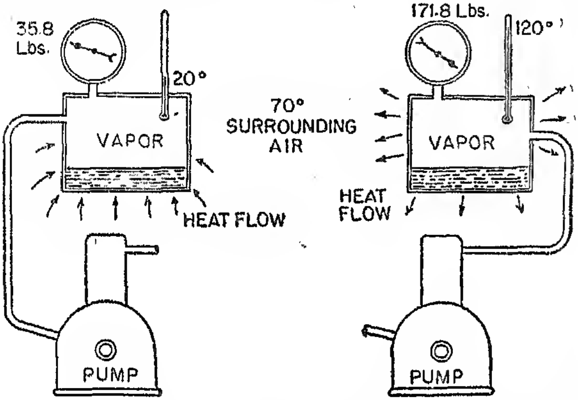

Fig. 4.—Reduction of Pressure Causes Evaporation and Absorption of Heat.

Fig. 5.—Increase of Pressure Causes Condensation and Loss of Heat.

hot tank out into the cooler air. But this means that the vapor is losing heat, and when this vapor loses heat it must condense. Consequently the vapor commences to condense into liquid, and it will continue to condense until either the surrounding temperature rises to correspond with the vapor pressure or until the pumping stops and the vapor pressure falls to the value corresponding to the surrounding temperature.

As you already will have realized, we have in Figs. 4 and 5 the essentials of a refrigeration sys-

tem. The tank and pump of Fig. 4 are the evaporator and compressor of Fig. 1, while the tank and pump of Fig. 5 are the condenser, the receiver, and the compressor of Fig. 1. The compressor acts as both a suction pump and a compression pump, pulling in low-pressure vapor on one side and discharging high-pressure vapor on the other side. Instead of the tanks of Figs. 4 and 5 we use the evaporator tubing coil and the condenser tubing coil of Fig. 1,

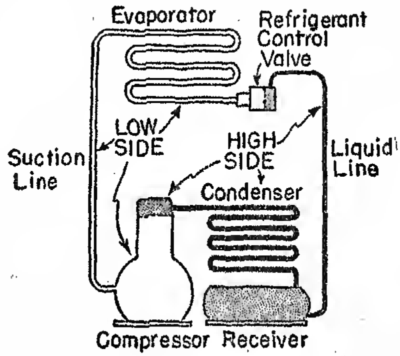

Fig. 6.—The Low Side and the High Side of a Refrigeration System.

because the coils allow more surface for transfer of heat.

High Side and Low Side.—All of the parts of the refrigerating system in which there is low-pressure refrigerant vapor are collectively called the *low side,* while all the parts in which there is high-pressure vapor or in which there is refrigerant liquid under high pressure are called the *high side.* In Fig. 6 the parts composing the low side are shown unshaded, and those composing the high side are shaded.

Temperature Control.—In the system that we are examining refrigeration takes place only while the

compressor operates to lower the pressure in the evaporator and to thus cause evaporation, absorption of heat, and lowering of temperature. The compressor ordinarily is driven by an electric motor. It would be entirely possible to provide a hand-operated switch for starting the motor and compressor every time that temperature should be lowered, and for stopping them when the temperature dropped to a desired level. But to make the system automatic in maintaining temperatures within a certain desired range it is necessary that the effects of temperature itself be made to start and stop the compressor. The effect ordinarily employed is that of the vapor pressure that accompanies certain temperatures of evaporating refrigerant.

The principle of one method of temperature control is illustrated by Fig. 7. A bellows is connected through a length of small tubing to the interior of the evaporator, so that pressure inside the bellows is the same as that inside the evaporator. A bellows is a thin-walled tube of flexible metal with the walls corrugated so that the effect is much like that in an accordion. Any increase of pressure inside the bellows causes it to lengthen, while a decrease of internal pressure causes it to shorten.

Expansion of the bellows is opposed by tension of a coiled spring, with the spring tension regulated by turning an adjusting screw. As the bellows expands against the tension of the spring it moves a pivoted arm carrying one of two contacts that form an electric switch, the other contact being stationary. The switch contacts are connected by electric wiring between the electric power line and the compressor motor. Closing the contacts starts the motor and compressor; opening them stops the motor and compressor. In actual constructions the switch con-

tacts are caused to close and open with a snap action, as is common practice in all electric switches.

Since pressure inside the bellows is the same as in the evaporator, and since evaporator pressure corresponds to evaporator temperature, the bellows will expand with the higher pressure that accompanies a higher temperature and will start the compressor. Compressor action will lower the tempera-

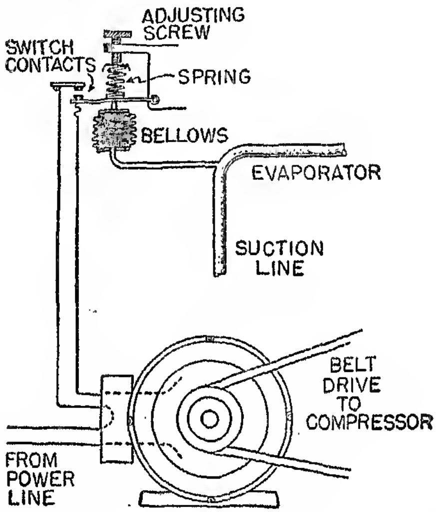

Fig. 7.—The Compressor May Be Started and Stopped by a Pressure-operated Switch.

ture and pressure in the evaporator and bellows, and at some certain low temperature the bellows will contract far enough to open the switch contacts and stop the compressor.

Instead of connecting the temperature-control bellows directly with the interior of the evaporator the bellows may be connected, as in Fig. 8, to a hollow bulb which is clamped to the evaporator.

This *thermal bulb* contains refrigerant vapor or contains refrigerant liquid and vapor. With a vapor-filled bulb the vapor expands as it warms up, just as air or any gas expands when heated, and increases the pressure in the bulb and bellows proportionately to the temperature of the bulb and evaporator. With a bulb containing liquid and vapor the effect of evaporator temperature is to evaporate liquid or condense vapor, and to increase or decrease the vapor pressure just as in the evaporator itself.

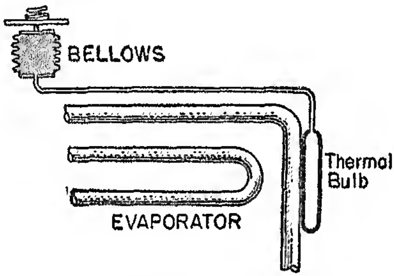

Fig. 8.—The Switch Bellows May Be Affected by Pressure from a Thermal Bulb.

Sometimes the thermal bulb is not placed directly on the evaporator, but is suspended in the space to be cooled or is placed within a liquid or other substance to be cooled. Then control is in accordance with the temperature of the space or substance refrigerated.

Heat Flow.—We already have noted the important fact that heat passes always from warmer to cooler bodies, but there are still other matters in relation to heat flow which we should understand before proceeding to examine refrigeration mechanisms and their operation.

Heat or heat energy may be transferred from

one part to another of a substance, or from one substance to another, in the three ways illustrated by Fig. 9. The first way is by *conduction,* which means the transfer of heat from something that is warmer to something that is cooler when the two are in direct contact. If you heat one end of a metal rod some of the heat flows by conduction through the rod and every part becomes warmer. In Fig. 9 we have a solid object partially immersed in a hot liquid, with the exposed portion in contact with a

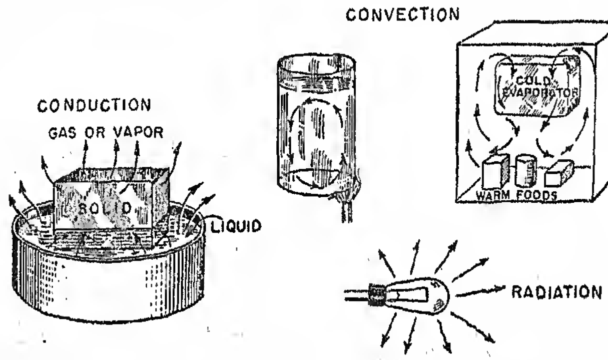

Fig. 9.—Heat Is Transferred by Any of the Three Processes of Conductión, Convection or Radiation.

cool gas. Heat flows by conduction from the liquid to the solid at their surfaces which are in contact, also from the liquid to the gas where these two are in contact. Heat flows by conduction from the solid to the gas where they are in contact. Heat flow by conduction occurs only between parts which touch one another.

Heat flows by *convection* from a warmer to a cooler body when it is possible for a liquid or a gas to move and to carry heat from one to the other. One of the illustrations in Fig. 9 shows a liquid being heated by a flame at one side of the container.

The warmed liquid becomes lighter than the cool portion, the cooler liquid pushes in under the lighter warm liquid, and a convection current is established as shown by arrows. Thus the heat is carried throughout the liquid-filled space.

In another illustration of Fig. 9 the air around warm foods in a refrigerator is warmed and thus made lighter in weight. The warmed air rises and flows around the evaporator, where it is cooled, becomes heavier, and falls down around the warm foods. Thus heat from the foods is transferred to the air by conduction, then convection currents of warmed air carry heat to the evaporator, which the heat enters by conduction.

Heat flows by *radiation* from every body to every other body which is cooler, with the flow taking place through any space which separates the bodies. Radiated heat acts like light; it flows through vacuums, gases and any transparent bodies, but is stopped by substances which are not transparent and warms these substances. Radiated heat flows with equal ease in all directions through a given medium, downward as easily as upward or sideways. It is reflected by anything that reflects light, and is absorbed by anything that absorbs light.

Measuring Heat.—The quantity of heat which is added to or removed from any body or any substance may be measured by the rise or fall of temperature per pound of the substance. The unit of heat quantity is called the British thermal unit. This name is abbreviated *Btu,* and we commonly speak of "bee-tee-you's" of heat. If the temperature of one pound of water rises one degree Fahrenheit, the one pound of water has absorbed one Btu of heat. If the temperature of the pound of water falls one degree, it has lost one Btu of heat.

The number of Btu's required to raise or lower

the temperature by one degree in one pound of any substance is called the *specific heat* of that substance. The specific heat of water is 1.0 (Btu) because it takes one Btu to change the temperature of one pound of water by one degree. Here are the specific heats of a few common substances.

SPECIFIC HEATS
Btu's per Pound

Air	0.24	Ice (at 0° F)	0.50
Aluminum	.21	Ice cream	.42
Beef, fresh	.77	Milk	.90
Beer	.90	Oil, petroleum	.51
Butter	.62	Oranges	.89
Eggs	.76	Steel	.12
Glass, plate	.16	Water	1.00

Heat quantities, specific heats, weight of a refrigerated substance, and degrees of temperature change are related as follows:

$$\textit{Btu's} = \textit{pounds} \times \textit{degrees} \times \textit{specific heat}$$

$$\textit{Degrees change} = \frac{\textit{Btu's}}{\textit{pounds} \times \textit{specific heat}}$$

Example: How many Btu's of heat must be removed to lower the temperature of 500 pounds of butter from 70° to 40°? Note that the temperature *change* is 30°.

$$\text{Btu's} = 500 \times 30 \times .62 = 930$$

Example: What will be the change of temperature, in degrees, when 2,000 Btu's of heat are removed from 100 pounds of fresh beef?

$$\text{Degrees change} = \frac{2000}{100 \times .77} = \frac{2000}{77} = 25.9^\circ$$

Sensible Heat and Latent Heat.—In Fig. 10 we have placed in a container exactly one pound of warm water, at a temperature of 115°, and underneath the container have a flame which raises the temperature of the pound of water from 115° to 212° in five minutes. At 212° the water will commence to boil. Boiling means that evaporation is taking place so rapidly as to form bubbles of vapor under the surface of a liquid.

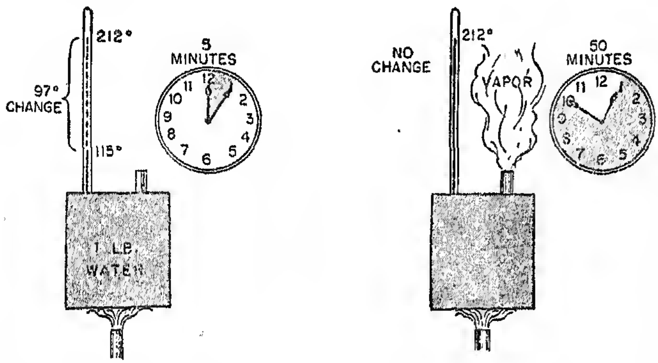

Fig. 10.—Sensible Heat Changes the Temperature. Latent Heat Changes the "State" but Not the Temperature.

We know that it takes one Btu of heat to raise the temperature of one pound of water one degree, and having raised the temperature 97° we must have added 97 Btu's of heat to the water.

Now, with the flame delivering heat at exactly the same rate as before, we allow all of the pound of water to boil away into vapor. The temperature remains right at 212° during the entire evaporating time, and the time is just 50 minutes. If we added 97 Btu's of heat in five minutes, in 50 minutes, which is 10 times as long, we must have added 970 Btu's of heat merely to cause evaporation without

changing the temperature of the water by even one degree.

Heat that changes the temperature of a substance, without changing the substance from solid to liquid or from liquid to vapor, is called *sensible heat.* It is so called because you can "sense" it by feeling a change of temperature. In Fig. 10 we added 97 Btu's of sensible heat to raise the water temperature from 115° to 212°.

Heat which does not change the temperature of a substance, but which changes the substance from a solid to a liquid or from a liquid to a vapor is called *latent heat.* Latent heat of fusion changes a substance from solid to liquid, as from ice to water, but without changing the temperature, which remains at 32° while the ice melts. Latent heat of evaporation changes a substance from liquid to vapor, as water or some liquid refrigerant to their vapors, but does not change the temperature. The latent heat of fusion appears in the resulting liquid, while the latent heat of evaporation appears in the resulting vapor. This means simply that the additional heat energy must be in the liquid or in the vapor in order that they may remain liquid or vaporous, and not return to solid or liquid forms.

The refrigerant Freon-12 has a latent heat of evaporation of 70 Btu's per pound at a temperature of zero, which means that one pound of this refrigerant will absorb 70 Btu's from surrounding objects while it evaporates and remains at a temperature of zero. It is this ability of liquids to evaporate, absorb heat, and lower the temperature of surrounding bodies without changing their own temperature that makes mechanical refrigeration the efficient process that it is.

Refrigerants.—Thirty or more different kinds of refrigerants have been used in various types of re-

frigerating systems. However, at the present time we find only five of them in general use for domestic refrigerators and for commercial installations of small and medium size. The four include Freon-12, Freon-114, Freon-22, sulphur dioxide, and methyl chloride. Freon-114 is especially adapted to use in rotary compressors, which have no reciprocating pistons but which compress the vapor with the help of sliding vanes and parts which have only a rotary motion. Methyl chloride is used chiefly in reciprocating piston compressors for commercial installations. Freon-12 and sulphur dioxide are used in both styles of compressors and in both domestic and commercial installations, although sulphur dioxide now is found chiefly in domestic jobs. Freon-22 is especially adapted to production of very low temperatures, such as 20 degrees below zero or lower.

Freon-12, and other refrigerants in the Freon group, are not poisonous. They are not irritating to the eyes, nose, throat or lungs. Their vapors, or mixtures of the vapors with air, are not explosive and they do not propagate flame. Rather they act as fire extinguishers. These refrigerants have a faint odor something like that of carbon tetrachloride. If inhaled in great enough concentrations, and for long enough, they will act like a mild anesthetic.

Sulphur dioxide is not poisonous to foods. Under all ordinary atmospheric conditions its vapor, or vapor and air mixtures, are not explosive nor will they burn. Sulphur dioxide has the highly irritating odor of burning sulphur, and if the vapor is inhaled even in mild concentrations it causes a violent strangling cough and the expectoration of blood stained mucus.

Methyl chloride is not poisonous to foods. It is non-irritating, having a faintly sweet and rather

pleasant odor, but is dangerous to breathe in any great concentration for even short periods. Because of this danger it is common practice to add acrolein, which has an irritating vapor and which gives warning of the presence of the methyl chloride. Methyl chloride is moderately flammable, and in some concentrations with air it will produce moderate explosions if ignited.

Since refrigeration systems are designed to operate efficiently with certain refrigerants, for which another is not substituted without suitable alterations, the technical behavior of the various substances is of more interest to the engineer than to the service technician. The exception is the relation between temperature and pressure at various operating conditions, a matter which later will be considered in connection with service operations.

CHAPTER 2

COMPRESSOR CONSTRUCTION

The compressor, its driving motor, the condenser, and the receiver for a refrigerating system frequently are constructed as an assembly on a single base or mounting and called the *condensing unit* or the *high side.* When such an assembly is called a high side, the evaporator and refrigerant control valve may be called the *low side.* This use of the terms high side and low side is approximately the same as explained in connection with Fig. 6.

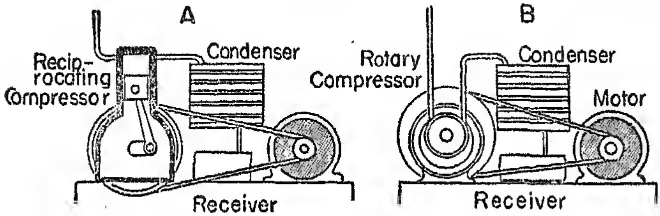

Fig. 11.—The Compressor May Be of the Reciprocating Piston Type, or Else a Rotary Type.

There are four general classifications for condensing units. First, as shown at *A* in Fig. 11, we may have a reciprocating piston type of compressor driven from a separate motor, and with a separate condenser and receiver. These parts are mounted on a base to form a unit. In some small installations the lower portion of the condenser acts as the receiver for liquid refrigerant, and there is no separate receiver tank.

Second, as at *B* in Fig. 11, we may have a rotary compressor instead of a reciprocating type, with no change in the remaining parts of the assembly.

In rotary compressors, which will be examined later on, there is no piston that moves up and down in a cylinder, or which reciprocates, but the principal moving part has a continual circular or rotary motion.

The third general class of condensing units, illustrated at *A* in Fig. 12, consists of a reciprocating compressor, with one or more pistons and cylinders, and the driving motor sealed in a gas-tight and moisture-tight housing. The condenser and receiver are outside the housing.

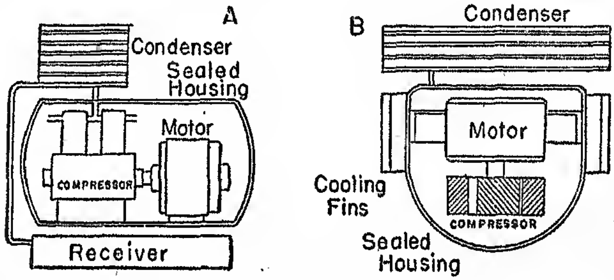

Fig. 12.—Sealed or Hermetic Units Have Compressor and Motor within a Gas-tight Housing.

The fourth general class of condensing units, shown at *B* in Fig. 12, makes use of a rotary compressor and its driving motor sealed within a tight housing. The condenser, and a separate receiver if used, are outside the housing. The sealed units of Fig. 12 are called *hermetic units,* since they are closed gas-tight or hermetically tight. Units such as shown in Fig. 11 are called *open units* to distinguish them from the hermetic types.

With hermetic units the vapor being pumped from the evaporator enters the sealed housing and fills this housing, then being drawn from the interior of the housing into the compressor. Since the compressor and motor are surrounded by refrigerant

vapor there is no need of an especially tight joint where the crank shaft or rotary drive shaft leaves the compressor and extends to the motor drive connection. With open units it is absolutely necessary that no refrigerant gas escape and no air enter around the compressor drive shaft, and rather elaborate sealing is needed at this point.

The shaft seals required with open type compressors are one of the most frequent causes for trouble with these systems. The hermetic types eliminate shaft seal troubles because there is no shaft seal and no need for one. This is the chief advantage of the hermetic unit. Its chief disadvantage is that servicing of the compressor or the motor is difficult or almost impossible in the field, and when these parts give trouble they must be removed from the system and taken to the shop.

Reciprocating Compressors.—Many of the features common to all reciprocating compressors are shown by Fig. 13, where it appears that the general construction is similar in many ways to that of automobile engines. The great majority of reciprocating compressors for domestic and commercial installations have vertical cylinders. Some industrial and air conditioning types have horizontal cylinders.

Cylinder heads are bolted on, with gasketed or ground joints for tightness. Discharge valves ordinarily are carried by a valve plate between the head and cylinder. Air-cooled compressors have extended thin fins to carry heat from the head and cylinder to the air which is circulated by a fan which often forms part of the flywheel or forms the flywheel spokes. Water cooled compressors have cylinder water jackets, and sometimes head jackets, much like those of automobile engines.

Piston rings and oil rings are used chiefly in com-

pressors where but little lubricating oil should circulate with the refrigerant. In systems where the oil mixes with the refrigerant, and passes through the entire system, piston rings may or may not be used. Pistons usually are of cast iron, piston pins of hardened steel, and connecting rods of forged steel.

Cylinders may be bolted to the crankcase, as in Fig. 13, or else the cylinder and crankcase may be

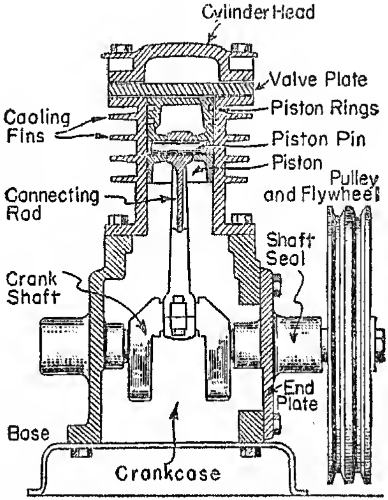

Fig. 13.—The Parts of a Reciprocating Piston Type of Compressor.

in one piece. Crankshaft end plates commonly are used to allow removal of the crankshaft after the connecting rod lower-end bearing is taken apart.

Many two-cylinder reciprocating compressors are in use. A section through one such design is shown by Fig. 14.

Suction Valves and Discharge Valves.—Reciprocating compressors require a suction valve somewhere between the suction line and the space be-

tween the top of the cylinder and the top of the piston, also a discharge valve between the top of the piston and the tubing line to the condenser.

Fig. 15 shows how suction valves may be located in the top of the piston and discharge valves in a valve plate between the cylinder and the cylinder head. Here the valves are indicated by flat discs

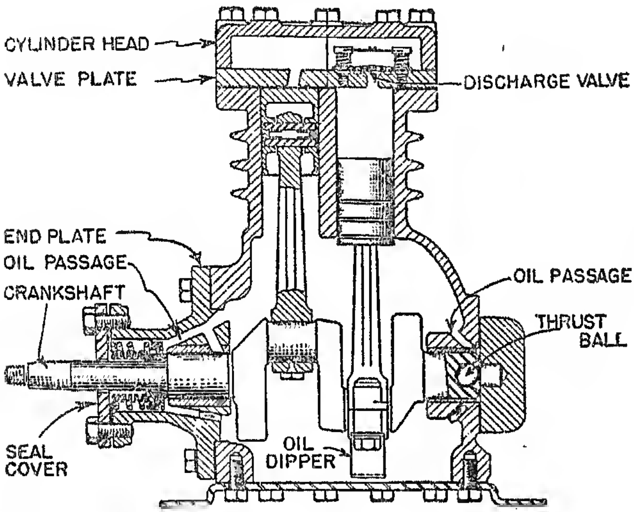

Fig. 14.—A Two-cylinder Reciprocating Compressor.

or plates above the openings or ports through which the vapor passes.

At *A* in Fig. 15 vapor from the suction line is drawn into the crankcase as the piston rises in the cylinder. As the piston descends, the discharge valve is drawn closed, the suction valve is drawn open, and vapor passes from the crankcase to the space above the piston. As the piston rises again the suction valve closes, the discharge valve is

forced open, and the vapor is compressed into the condenser.

At *B* of Fig. 15 the action is similar to that at *A* in that vapor is drawn into the crankcase and then passes through the suction and discharge valves. But here, when the piston gets to the bottom of its stroke it uncovers ports through the cylinder wall which communicate with the suction line connection, and additional vapor comes through these ports into the space above the piston.

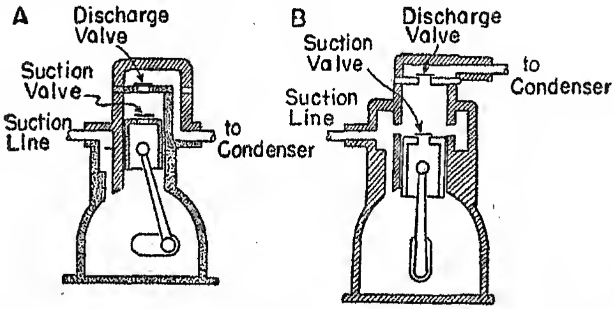

Fig. 15.—Suction Valves May Be in the Top of the Piston, with Discharge Valves in a Valve Plate.

Fig. 16 shows how both the suction valve and the discharge valve may be placed in a valve plate. As the piston descends in the cylinder both valves are pulled downward, which opens the suction valve and closes the discharge valve to draw the cylinder space full of vapor from the suction line. As the piston ascends, both valves are forced upward, closing the suction valve and opening the discharge valve as the vapor is forced into the condenser and compressed. The crankcase relief opening allows vapor to enter and leave the crankcase as the piston moves up and down, thus preventing sudden changes of crankcase pressure as movement of the piston alters the volume of the crankcase space.

Valve Constructions.—Many different designs of suction and discharge valves are used in reciprocating compressors. As a general rule the type of valve is the same or similar for both suction and discharge valves in any one compressor.

At *A* in Fig. 17 is a *diaphragm* type of valve consisting of a circular piece of very thin and very flexible steel whose outer flat portion rests on top of a finished surface in which are a number of ports arranged in a circle. The diaphragm is held

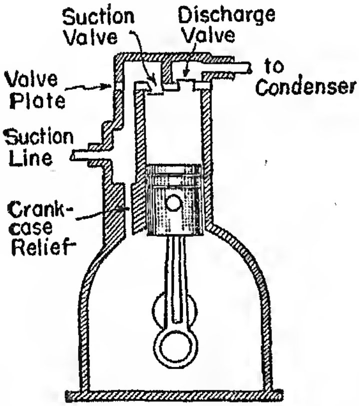

Fig. 16.—Both the Suction Valves and the Discharge Valves May Be in a Valve Plate.

securely at its center. When vapor pressure underneath the diaphragm exceeds that on top the edge of the diaphragm flexes and permits vapor to flow through.

At *B* in Fig. 17 is a *ring* valve consisting of a flat circular disc with a large central circular opening. This flat ring rests on top of a number of valve ports arranged in a circle, with the flat underside of the ring held against the flat finished surface around the ports by a number of small coiled springs.

Pressure from underneath raises the ring and permits passage of vapor through the ports.

Fig. 18 shows two styles of *reed* valves. At *A* there is a reed of thin, flexible steel clamped securely at one end, and at the free end resting on the finished surface around one or more ports. Pressure

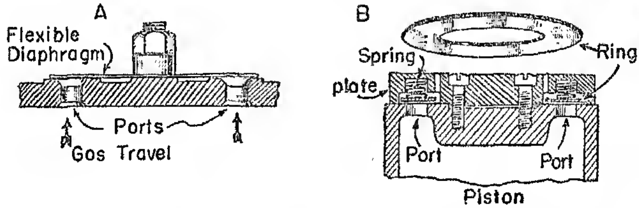

Fig. 17.—A Diaphragm Valve (A) and a Ring Valve (B) as Used in Compressors.

from below raises the valve from the port opening and permits flow of vapor. At *B* an oblong flexible reed is held in place and limited in its rise by a heavier rigid beam. Pressure from below causes the thin reed to flex upward against the beam and to open the port for flow of vapor.

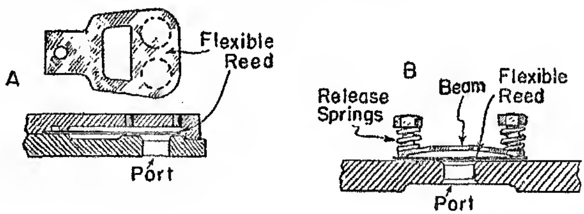

Fig. 18.—Two Types of Reed Valves.

The rigid beam which retains the reed at *B* in Fig. 18 is itself held down by two rather strong coiled springs. Should liquid refrigerant or refrigerant and oil come through the port, as sometimes may happen, the beam and the reed are both lifted

against the tension of the release springs. This temporarily affords a passage of large area for the "slug" of liquid, and prevents damage to the flexible reed.

At *A* in Fig. 19 is shown a simple type of *disc* valve which rests by its own weight on top of the port and is prevented from lifting more than a very little way by a retaining ring that snaps into a groove or recess. At *B* is a disc valve held against the surface around the port by a light coiled spring. A retainer holds this light spring, limits lift of the

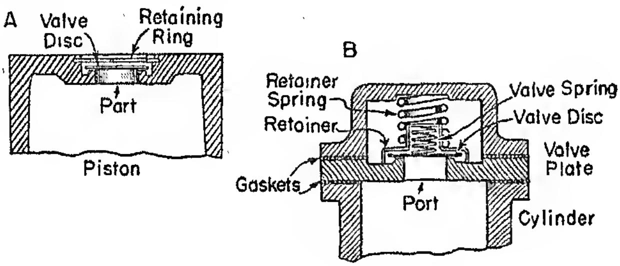

Fig. 19.—Two Types of Disc Valves.

disc, and is itself held down by a heavier and stronger coiled spring. Should liquid refrigerant or oil be forced through this valve, the disc rises against the retainer and the retainer lifts against the tension of the retainer spring to afford the large opening which will prevent damage while the liquid passes through.

Rotary Compressors.—The construction principle of one type of rotary compressor is shown by Fig. 20. Within an outer shell partially filled with lubricating oil is a stationary housing with a cylindrical or drum-shaped interior. Within this housing is a rotating ring carried around by a circular disc attached to the drive shaft, but having its center offset or eccentric in relation to the center of the

shaft and of the housing. The outer circumference of the eccentric ring and the inner circumference of the housing practically touch at the point where they are closest. A blade, of rectangular cross section, is free to slide endwise in its slot, and is held snugly against the eccentric ring by a coiled spring. With the eccentric ring rotated in the direction shown by an arrow, the suction line is brought in below the sliding blade and the discharge connection is above the blade.

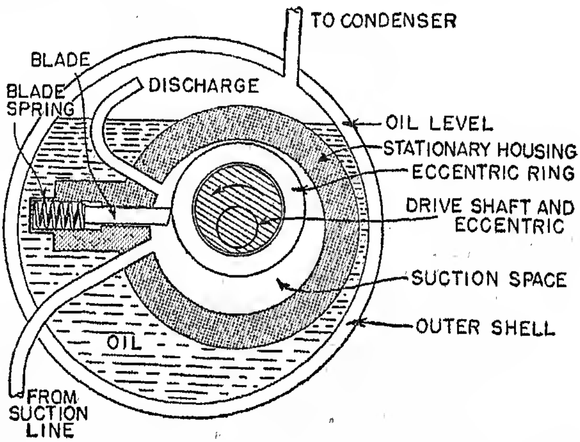

Fig. 20.—A Rotary Compressor with a Single Sliding Blade or Vane.

The operating principle of this compressor is illustrated in Fig. 21. At *A* there is a very small space between the blade, the eccentric ring and the housing at the point where the suction line connects. As the eccentric ring is rotated to the position shown at *B* this space connected to the suction line becomes larger in volume. With continued rotation the suction space becomes still larger at *C* and of almost its maximum possible volume at *D*. This continual

enlargement of the space connected to the suction line draws vapor into the compressor from the evaporator.

On the following revolution of the eccentric ring, which we may consider as commencing at diagram *A*, the vapor which has been drawn in is cut off from the suction line by the blade, and since the point of contact of the eccentric ring with the housing now has passed the blade position, the vapor

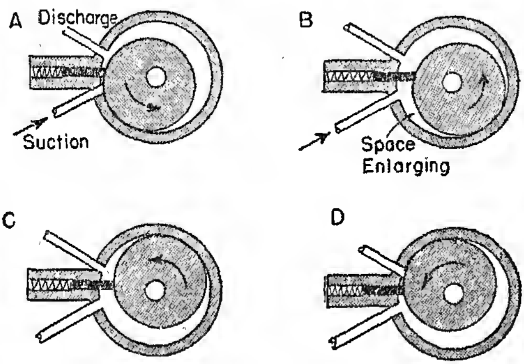

Fig. 21.—How the Single-blade Rotary Compressor Operates.

in this space may flow into the discharge line. As the eccentric ring rotates to position *B* this space connected to the discharge line becomes smaller, at *C* it is still smaller, and at *D* is of almost minimum possible volume. This contraction of the space in which is the vapor forces the vapor through the discharge line and compresses it in the condenser.

While vapor is being compressed and discharged to the condenser from the space on one side of the blade, more vapor is being drawn into the compressor by the expanding space on the other side of the blade. The actions of suction, compression

and discharge continue as long as the compressor operates.

Fig. 22 shows a type of rotary compressor in which there are four sliding blades carried by a rotor which is turned by the drive shaft and whose center is offset or is eccentric in relation to the housing in which it revolves. The outer ends of the four blades usually are held snugly against the inner circumference of the housing by springs, but sometimes by the centrifugal force developed by their

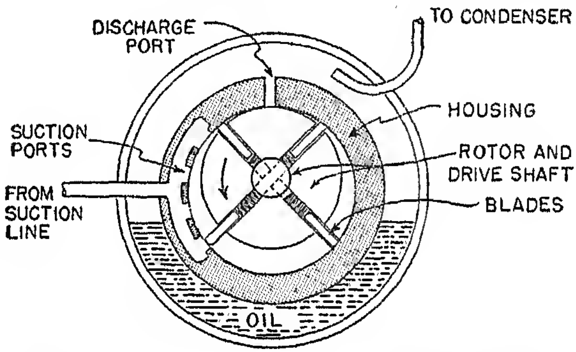

Fig. 22.—A Rotary Compressor with Four Sliding Blades or Vanes.

rapid rotation. The spring recesses may extend only part way into the rotor or may go all the way through, as shown, with spacing pins between blades that are opposite each other.

Vapor from the suction line passes through the suction ports into the space between the rotor, the housing, and two adjacent blades. As the rotor revolves in the direction of the arrow, the space enlarges its volume. The volume becomes maximum just as the rear blade passes the last suction port. Then, with continued rotation, this vapor-filled space becomes smaller and smaller to compress the vapor

within it. At the end of the revolution which commenced with suction the confined vapor is compressed and is discharged through the discharge port to the space within the shell, from which it passes to the condenser.

While a rotary compressor is idle there is opportunity for warm vapor from the compressor spaces to be forced back into the evaporator. To prevent such action a one-way check valve may be installed in the suction line near the compressor. This valve permits free passage of vapor from the suction line into the compressor but prevents a reverse flow.

Shaft Seals.—At *A* in Fig. 23 is represented the end of a compressor shaft that extends out through the compressor housing to the driving pulley or the driving motor connection. The shaft is supported by a bearing. Between the shaft and its bearing must be a few thousandths of an inch clearance to permit free rotation of the shaft. If the pressure in the crankcase or housing of the compressor is lower than that of the surrounding air the outside air will leak into the compressor through the bearing clearance. If the pressure in the compressor is higher than that of the surrounding air, and if there is refrigerant vapor in the crankcase, some of the vapor will leak out of the compressor.

At *B* in Fig. 23 we have commenced the installation of a *bellows seal* to prevent leakage of air and refrigerant vapor. Against the shoulder of the shaft is pressed a seal ring made of bronze or other material between which and the steel of the shaft there is relatively little friction. One end of a flexible corrugated metal bellows is attached to the seal ring and the other end of the bellows is attached to a disc that is clamped securely between the end of the housing and the cover plate.

Vapor escaping from the compressor would enter

the space outside the bellows, but could not pass through to the outer air because of the gas-tight bellows and sealing contact between the seal ring and shaft. Air attempting to enter the compressor would pass first to the space inside the bellows, but

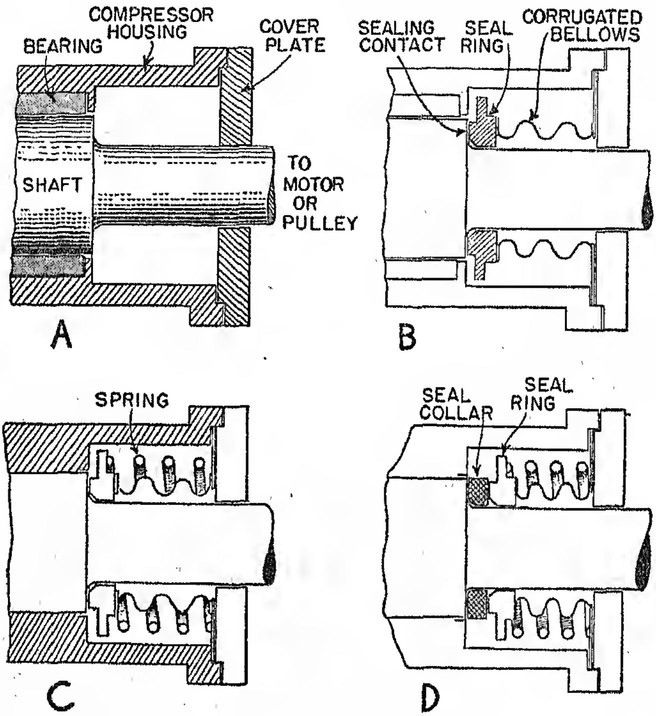

Fig. 23.—The Construction of One Style of Bellows Seal for a Compressor Shaft.

would not get through the bellows and sealing contact. The bellows and seal ring remain stationary while the compressor shaft revolves.

To maintain the pressure which will insure a good sealing contact we place, in illustration *C*, a coiled

spring between the seal ring and the cover plate, so that the ring always is pressed against the shaft shoulder.

Many bellows seals are constructed about as shown at *C*, with the seal ring bearing against the shoulder of the shaft. To prevent the wear on the shaft caused by its rotating against the stationary seal ring we find in many bellows seals an extra seal

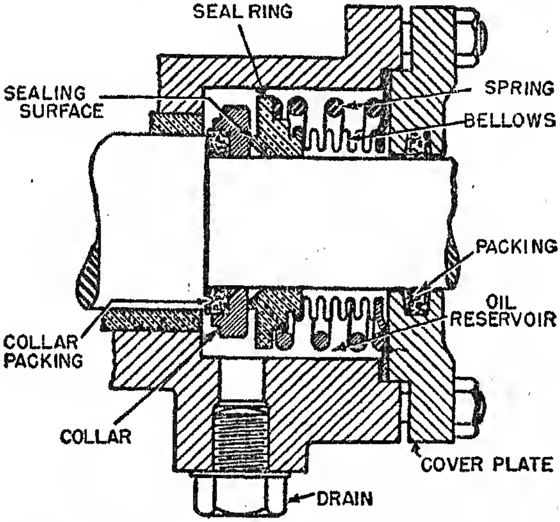

Fig. 24.—A Bellows Seal Having a Seal Ring and a Packed Collar.

collar between the shaft shoulder and the seal ring, as at *D*. The seal collar fits snugly on the shaft and rotates with the shaft, while the seal ring remains stationary. When excessive wear develops on the seal collar, the seal ring, or both, or when for any reason the sealing contact between them becomes ineffective, both of these parts may be replaced. Otherwise the shaft shoulder must be dressed or

lapped to make it smooth again, and a new seal ring installed. Fig. 24 shows details of a bellows seal of the same general type we developed in Fig. 23.

To lubricate the sealing contact, oil from the compressor oiling system is admitted to the seal compartment or else the compartment is partially filled with oil which is drained and replaced at intervals.

As shown by Fig. 25, some shaft seals are constructed with the spring inside the bellows rather than outside. The functions of the parts and the

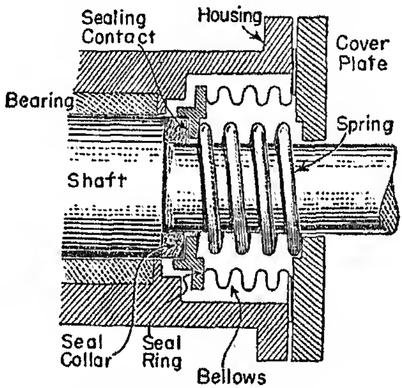

Fig. 25.—The Shaft Seal Spring May Be Inside the Bellows.

operating principles are not altered by relative location of the spring and bellows. Still other types of shaft seals have been made with no bellows, but with a stationary ring held against a rotating ring by means of a coiled spring.

Fig. 26 shows the construction of one style of *diaphragm seal* in which a circular disc diaphragm of thin flexible metal is used somewhat similarly to the bellows in the bellows type of seal. The diaphragm flexes against a raised fulcrum ring in the

cover plate to maintain a practically steady pressure between the sealing contact surfaces with changes of pressure inside the compressor housing. The diaphragm type of shaft seal is not so commonly used as is the bellows type.

Compressor Lubrication.—The internal working parts of small reciprocating compressors usually are

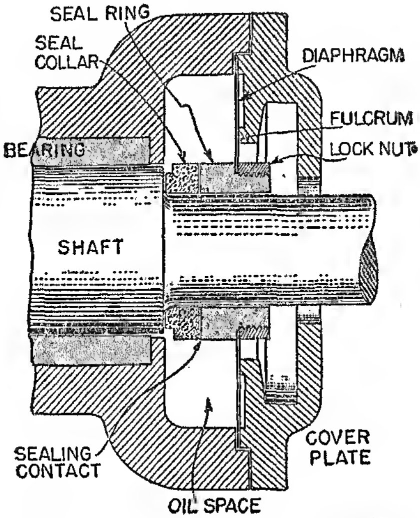

Fig. 26.—A Diaphragm Type of Shaft Seal.

lubricated by means of a *splash oiling* system. With this system a rather large quantity of oil is in the lower part of the crankcase. Extension lips or splashers on the bottom of the connecting rods, shown in Fig. 14, splash oil onto the cylinder walls for cylinder-to-piston lubrication. Oil enters the crankshaft bearings and the lower connecting rod bearings through holes drilled through the bearing supports. Oil reaches the piston pin bearing from the cylinder walls, also through holes in the top of

the piston bosses that carry the piston pin. Fig. 14 shows oil passages through which oil draining back from the splash enters the crankshaft end bearings, also the shaft seal compartment.

The blades, rings and housings of rotary compressors usually are lubricated by immersing these parts in a body of oil carried inside the shell. This is illustrated in Figs. 20 and 22.

Large reciprocating compressors, most of the high speed types, and some of the smaller sizes, are

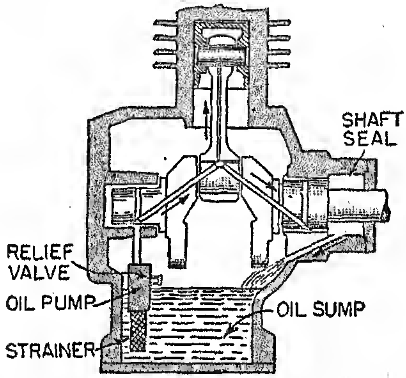

Fig. 27.—Oil Passages and Oil Flow for Force-feed Oiling.

lubricated by *force-feed oiling* with which a pump forces oil under pressure to all the important bearing surfaces. Such a system is illustrated by Fig. 27. A pump driven from the crankshaft draws oil through a fine-mesh wire gauze strainer from the oil reservoir or oil sump in the crankcase. Oil is delivered to one of the crankshaft bearings, from where it flows through holes drilled through the crankshaft to the connecting rod bearing or bearings and then to the other crankshaft bearing. From this second crankshaft bearing oil passes through the shaft seal compartment and then re-

turns to the crankcase to be re-circulated. From each connecting rod bearing a small tube or a drilled hole leads to the piston pin bearing for that rod. The cylinder walls and pistons are lubricated by oil thrown out from the connecting rod bearings and escaping from the piston pin bearings.

The oil pump, or the line leading from the pump, is fitted with a pressure relief valve which opens against spring tension should pressure rise to a value which might damage the pump. Excessive

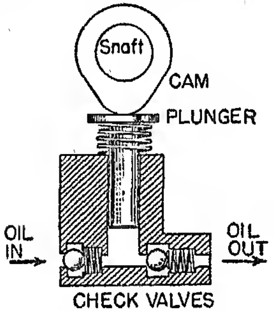

Fig. 28.—A Plunger Type of Oil Pump.

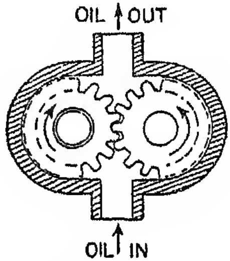

Fig. 29.—A Gear Type of Oil Pump.

pressure may be due to clogging of the passages, to incorrect oil, or to oil that has thickened from cold.

Three types of oil pressure pumps are in use; the reciprocating plunger pump, the gear pump, and the rotary pump. The principle of the plunger pump is shown by Fig. 28. The cylindrical plunger is pressed downward by a cam or eccentric on the compressor shaft or an auxiliary gear-driven shaft, and is lifted by a coiled spring as the cam rotates. Two check valves are held closed by springs. The inlet check valve may open into the pump barrel against its spring, and the outlet valve may open outward from the barrel. The inlet valve opens as the plunger

rises, and admits oil which is discharged through the outlet valve as the plunger is pressed down.

The principle of the gear pump is shown by Fig. 29. Two spur-tooth gears mesh together inside of a closely fitted housing. One gear is driven by some rotating part of the compressor, and it drives the meshing gear. Oil is drawn into the bottom of the housing, is caught between the housing walls and the teeth of the gears rotating as shown by arrows, and is expelled at the top because it cannot pass back through the point at which the gear teeth mesh together.

The rotary pump operates on the same principle as the rotary compressor that has four blades (Fig. 22) but the pump usually has but two blades placed opposite each other on the rotor.

Sealed compressors or hermetic compressor units usually are partially filled with oil which is circulated by means of a gear pump or rotary pump to keep the working parts flooded with lubricant. The pump is within the sealed shell.

Reciprocating compressors may have an oil-level checking rod which extends down into the oil reservoir through an opening high up on one side of the case. The rod is lifted out and examined to note the height to which liquid oil extends, as shown by markings on the rod. Rotary compressors, and many also of the reciprocating type, have sight glasses or bull's-eyes fitted to the crankcase or shell so that the oil level may be observed through them.

CHAPTER 3

REFRIGERANT CONTROL VALVES AND EVAPORATORS

Between the condenser or the receiver and the evaporator there must be a valve or some equivalent device which will admit liquid refrigerant to the evaporator as rapidly as the liquid is evaporated and drawn away through the suction line. The simplest of all arrangements for controlling the rate at which liquid refrigerant may enter the evaporator is simply a restricted opening through which refrigerant liquid will be forced at the desired rate by the difference between pressures in the condenser or receiver and in the evaporator.

The principle of a *restrictor* for liquid refrigerant is illustrated in Fig. 30. Pressure built up in the condenser by the compressor forces refrigerant through a strainer and the liquid line to the restrictor, from which it issues into the spaces of the evaporator as a liquid and changes to vapor as heat is absorbed.

Capillary Tubes.—Another device which acts quite similarly to a restrictor is the capillary tube, the principle of whose application is illustrated by Fig. 31. The capillary tube usually has an internal bore or opening only four or five hundredths of an inch in diameter. The tubes commonly are anywhere from four to 20 feet in length. The higher the evaporator temperature, the higher the vapor pressure in the evaporator, and the less the difference between evaporator and condenser pressures, the shorter is the capillary tube. This is because the smaller pressure difference requires less retarding effect to limit the liquid flow to a given rate.

Capillary systems of one kind or another are in general use for domestic refrigerators. In addition to their simplicity and freedom from moving parts they have the advantage that after the compressor stops, enough additional refrigerant flows through the capillary or the restrictor to equalize the pressures in the low side and high side of the system. This reduction of pressure in the condenser and

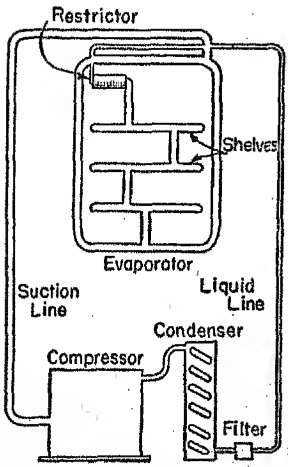

Fig. 30.—A Restrictor Admits Liquid Refrigerant to the Evaporator.

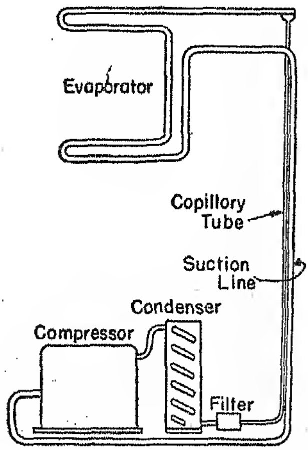

Fig. 31.—A Small-bore Capillary Tube Feeds Liquid to the Evaporator.

high side permits the compressor to start again with much less power than required when the high side pressure is maintained high between operating periods.

With the capillary systems it is necessary to provide enough liquid capacity in the low side so that there is no chance for any liquid to be drawn over into the compressor, through the suction line, when the compressor starts. This accumulator capacity

usually is around eight to twelve cubic inches. Filters are placed between the condenser and the capillary tubing to prevent entrance of foreign matter to the tubing, whose very small bore quickly would be clogged.

High Side Float Valves.—In Fig. 32 the flow of refrigerant from the condenser to the evaporator is controlled by a float valve placed in the high side of the system, between condenser and evaporator.

Condensed liquid refrigerant from the condenser is forced into the top of the float tank. As the liquid level rises in the tank the hollow buoyant metal float is raised and opens the float valve to allow liquid from the float tank to pass into the suction line. As soon as a small quantity of liquid has passed, the level drops, the float falls with it, and the valve is closed to shut off the flow. Thus we have liquid refrigerant delivered through the liquid line as fast as the refrigerant vapor is condensed.

Between the float valve and the evaporator of Fig. 32 is a *liquid pressure valve,* here shown as consisting merely of a rather heavy weight against whose downward pressure the liquid refrigerant must be forced before it can pass to the evaporator. Equivalent pressure might be secured with a spring acting on a valve of light weight. The purpose of the liquid pressure valve is to maintain a fairly high pressure on the liquid refrigerant in the long, exposed liquid line. Were there no pressure valve, the liquid refrigerant would be subjected, as soon as it passed the float valve, to a pressure almost as low as that in the evaporator. Then evaporation would commence in the liquid line and we would have refrigeration in this line as well as in the evaporator. In addition to wasting power due to useless refrigeration outside the evaporator, the resulting low

temperature of the liquid line would cause condensation on it of water from the surrounding air and we would have undesirable "sweating" of this line.

Fig. 33 shows a high side float system without a liquid pressure valve. However, an equivalent effect is secured by using a long liquid line of small internal diameter or bore, which really is a capillary

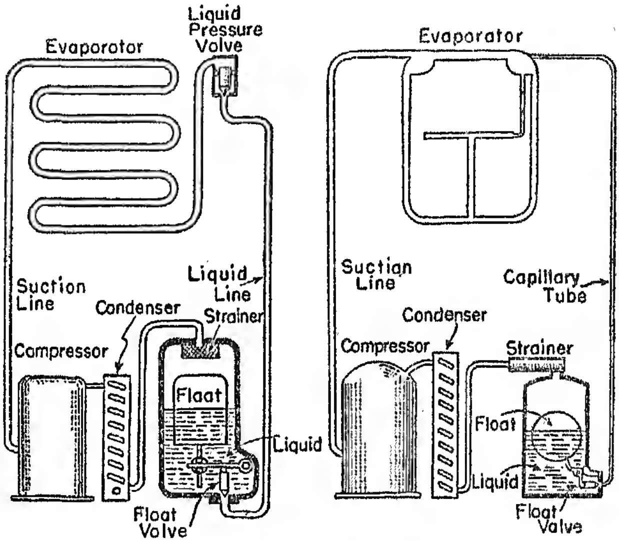

Fig. 32.—A High-side Float System with a Liquid Pressure Valve.

Fig. 33.—A High-side Float System with a Capillary Tube.

tube. The resistance or friction of the small-bore capillary tubing opposes flow of liquid through it, and this opposition means that pressure between the ends of the tubing must be high in order to force liquid through it. The high pressure prevents evaporation, refrigeration, and resulting sweating at the capillary liquid line.

High side floats are common in domestic refrigerators. They are used with open systems having either reciprocating or rotary compressors, also with hermetic systems or sealed systems.

Low Side Float Valves.—Fig. 34 shows how a float and float valve may be placed in the low side of the system instead of in the high side. The evaporator consists of a cylindrical header or tank from which

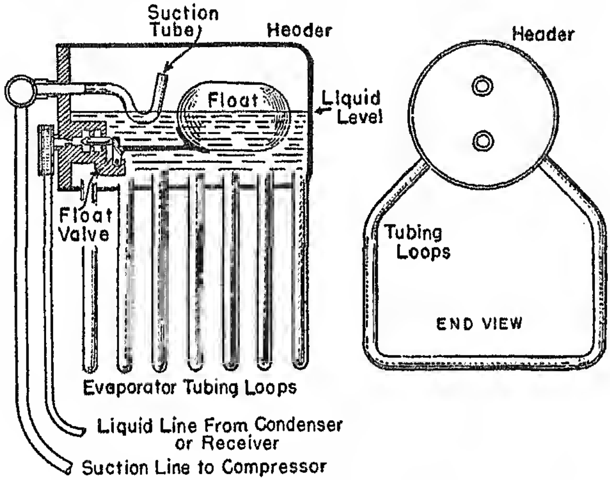

Fig. 34.—A Low-side Float and Float Valve Admit Refrigerant to the Evaporator Header.

a number of tubing loops extend sideways and downward. Within the header is the float and its valve. The float valve, when open, admits liquid refrigerant from the liquid line. When the liquid level rises, the hollow buoyant float will have been carried high enough to close the float valve. As refrigerant evaporates, the vapor is drawn out of the header through the open-ended suction tube which is an extension of the suction line. Evaporation lowers the liquid level and the float, the float

valve opens and admits more liquid refrigerant to replace that which has been turned to vapor.

The loops of evaporator tubing are kept full of liquid refrigerant, and as the refrigerant absorbs heat it boils within the tubing. The bubbles of vapor rise into the space above the liquid in the header, and the vapor goes through the suction line.

Conditions of Refrigerant in Evaporator.—The refrigerant in an evaporator may exist in any one or more of the conditions represented by Fig. 35. Which of the conditions are present, and the extent to which each is present, depend on the design of the apparatus and on the manner in which it is operated. Much depends on the type of refrigerant control, on whether it is a capillary, a float valve, or some other kind of valve.

The liquid refrigerant is under compression in the condenser, receiver, and liquid line. Between the liquid line and the entrance to the evaporator we must have some form of restriction which divides the high side or high-pressure side of the apparatus from the low side or low-pressure side. As the *high-pressure liquid* refrigerant escapes through the restriction into the low-pressure evaporator it is, for an instant, *low-pressure liquid.* But the drop of pressure immediately causes evaporation and absorption of heat. The evaporation within the liquid causes bubbles of vapor to appear in the body of liquid, and we say that the liquid refrigerant is *boiling.* The action is like that which causes bubbles below the surface of water which is boiling.

As the refrigerant continues on through the evaporator the liquid no longer exists as a continuous body containing vapor bubbles, but the refrigerant changes to a body of vapor in which drops of liquid are being carried along. This mixture of vapor and liquid is called *wet vapor.*

As the last of the liquid drops evaporate we have remaining only a *saturated vapor.* A saturated vapor is one consisting of the maximum quantity of refrigerant which can exist as a vapor with the combination of pressure and temperature which are present. If pressure is increased some of the vapor will condense to liquid and we have wet vapor. If pressure is decreased there would be additional

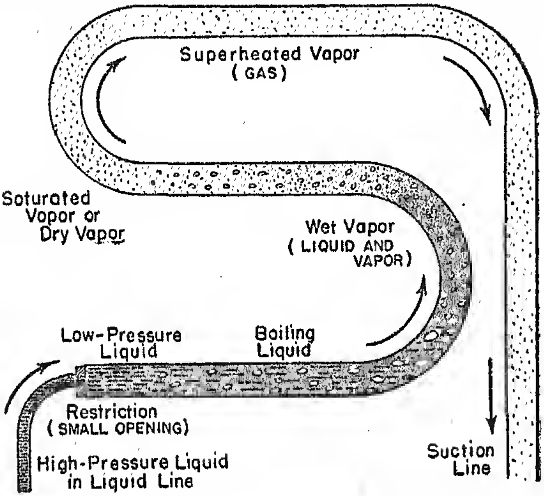

Fig. 35.—The Various Conditions in Which Refrigerant May Exist within an Evaporator.

liquid evaporated were liquid available for evaporation. But in the portion of the evaporator where we have saturated vapor there is no more liquid available, so the decrease of pressure simply would mean a decrease in the quantity or weight of vapor in a given volume. There would be less vapor, or a lesser density of vapor, than corresponding to saturation at the existing temperature.

If the temperature of a saturated vapor is low-

ered, some of the vapor will condense to liquid form and we shall have wet vapor. If the temperature is raised there would be additional evaporation were liquid available, but with no liquid to be evaporated the temperature of the vapor rises, the vapor expands due to its higher temperature, and we have less vapor density—just as we have with the decrease of pressure mentioned in the preceding paragraph.

The temperature of the saturated vapor is raised because of heat being absorbed through the evaporator, and the density may become less because of suction from the compressor. A vapor whose temperature is higher than the temperature for saturation at the existing pressure is called a *superheated vapor*. The number of degrees by which the actual vapor temperature exceeds the temperature for saturation at the existing pressure is called the *superheat*.

Superheated vapor frequently is spoken of as *gas*. In fact, vapor in any condition often is called gas. The name gas commonly is applied to whatever substances are best known in their gaseous states rather than as liquids or solids. Strictly speaking, a gas cannot be condensed by applying pressure at any attainable temperature, while a vapor may be condensed by a reduction of temperature or an increase of pressure. Thus air, oxygen and such substances are gases, while evaporated refrigerants are vapors.

Superheat in Refrigeration.—Let's consider the relations between temperature and heat absorption of one pound of Freon-12 refrigerant as it passes through the evaporator when the suction pressure is maintained at 30 pounds per square inch, assuming that the high-pressure liquid in the liquid line is 70° F.

The evaporation temperature for a pressure of

30 pounds is 11.1° F., so this is the temperature at which the liquid refrigerant will evaporate and absorb heat in the evaporator. To lower the temperature of the entering liquid refrigerant from 70° to 11.1° we must remove only about one-quarter Btu of heat from the pound of Freon-12. That is, we actually must refrigerate the refrigerant.

Then the pound of refrigerant liquid remains at a temperature of 11.1° while it evaporates into vapor which also is at 11.1°. During this evaporation the pound of refrigerant absorbs 68.86 Btu's of heat. About a quarter of a Btu is absorbed from another pound of liquid refrigerant whose temperature is being lowered from 70° to 11.1° as it enters the evaporator, and all the rest is absorbed from whatever is being refrigerated by means of the evaporator.

Now we have a pound of saturated vapor or a pound of dry vapor at a temperature of 11.1° in the evaporator. Because this temperature is lower than that of substances around the evaporator, the cold saturated vapor absorbs additional heat and becomes superheated vapor. If enough additional heat is absorbed to raise the temperature of the vapor by 10°, to 21.1°, we have a superheat of 10°. To raise the temperature of the pound of vapor by 10° takes only about 1¼ Btu's of heat.

The heat absorbed by vapor as it superheats is negligible in comparison with that absorbed during evaporation from liquid to saturated vapor with no change of temperature. For all practical purposes of refrigeration of surrounding substances the portion of the evaporator in which superheating takes place is wasted. The only effective portion of the evaporator is that in which we have boiling liquid, wet vapor, and saturated vapor.

If the superheated vapor extends more than a very

little way back into the evaporator, from the suction line end, we are wasting a considerable portion of the heat-absorbing surface of the evaporator. On the other hand, if there is no superheating in the evaporator, and saturated or wet vapor goes over into the suction line, we are wasting some of the evaporation and heat absorption in the suction line, are cooling the suction line to a point at which it sweats, and may allow liquid refrigerant to get into the compressor where it may cause valve troubles.

Manual Control of Refrigerant.—The capillary tube admits refrigerant to the evaporator at a rate proportional to the difference between compression and suction pressures. The high side float valve admits refrigerant as fast as it is condensed, and this corresponds to the rate of evaporation and of pumping through the compressor. The low side float admits refrigerant at the same rate at which the liquid is evaporated. Instead of using any of these automatic controls it would be entirely possible to provide nothing more than a hand-operated or manually operated needle valve which could be set to admit refrigerant at a constant rate proportional to the difference between suction and compression pressures.

A manual control frequently is used in large plants where someone always is in attendance to watch temperatures and pressures, and where the rate at which heat is to be removed from refrigerated substances remains practically constant. Otherwise some form of automatic control must be used.

X **Thermostatic Expansion Valve.**—In Fig. 36 is illustrated the principle of a thermostatic expansion valve system of control which admits refrigerant to the evaporator in accordance with the degree of superheat existing at the evaporator outlet. This

general method of control is common in commercial installations but is rare in the newer models of domestic refrigerators.

Within the thermostatic expansion valve of Fig. 36 is a flexible diaphragm of thin metal. The space

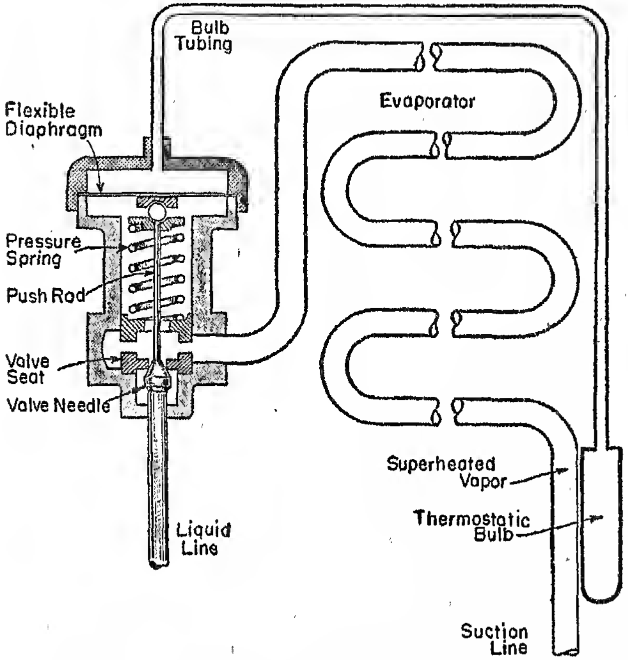

Fig. 36.—The Principal Parts of a Thermostatic Expansion Valve.

above the diaphragm is connected through a small tube to a *thermostatic bulb* clamped securely to the suction line just where it leaves the evaporator, at a point where the suction line contains superheated vapor. Inside the bulb is refrigerant liquid and vapor or else vapor alone. The vapor extends

through the bulb tubing and fills the space above the valve diaphragm.

The underside of the flexible diaphragm is exposed to the pressure at the entrance to the evaporator. When pressure from the thermostatic bulb exceeds that at the evaporator entrance by an amount sufficient to overcome tension of the valve spring, the diaphragm flexes downward, moves the push rod down, presses the valve needle away from the valve seat, and allows liquid refrigerant from the liquid line to enter the evaporator. When bulb pressure is less than enough to overcome spring tension and evaporator pressure the diaphragm flexes upward and closes the liquid valve to shut off refrigerant.

If the refrigerating mechanism has been idle for some time the pressure in the bulb, the tubing and above the diaphragm is almost enough to overcome the tension of the valve spring and open the valve. As soon as the compressor starts it lowers the pressure in the evaporator and in the portion of the valve under the diaphragm. The decreased pressure under the diaphragm allows bulb pressure to force the diaphragm down and open the liquid valve.

Liquid refrigerant now comes through the opened valve as a spray, and the evaporator fills with wet and saturated vapor. If all liquid is evaporated and becomes superheated vapor before reaching the suction line, more liquid continues coming in, heat continues to be absorbed from around the evaporator, and this action goes on until surrounding temperature becomes so low that wet and saturated vapor extends nearly all the way through to the point where the bulb is clamped to the suction line. Then the lessened degree of superheat at this point cools the suction line and bulb, the vapor pressure decreases in the bulb and above the diaphragm, and

the diaphragm is raised by spring tension to close the valve either wholly or partially. This stops refrigeration, or reduces it, until there is enough superheat at the bulb position to raise the bulb temperature, increase the vapor pressure in the bulb and above the diaphragm, and again open the valve from the liquid line.

In the thermostatic bulb and in the space above the diaphragm is the same kind of refrigerant used in the evaporator. Consequently, with the mechanism idle and with the same temperature at the end of the evaporator and in the thermostatic bulb, the pressure above the diaphragm will be the same as that below the diaphragm, and the spring tension keeps the valve closed. The amount of tension on the spring determines the excess of pressure from the bulb that is required for pushing down the diaphragm and opening the valve. The excess of pressure from the bulb, compared with that at the evaporator entrance and under the diaphragm, depends entirely on the degree of superheat in the evaporator at the bulb position. Therefore, adjustment of the spring tension determines the degree of superheat that must be present to open the valve, and the degree below which the valve will be closed. Because the same refrigerant is in the bulb and above the diaphragm as in the evaporator and under the diaphragm, temperature and pressure changes in one part will be proportional to those in the other.

Fig. 37 shows the principal operating parts of a style of thermostatic expansion valve in which a flexible metallic power bellows replaces the flexible diaphragm of Fig. 36. The interior of this power bellows is connected through tubing to the thermostatic bulb. Increase of vapor pressure from the bulb tends to extend the power bellows, while decrease of bulb pressure allows this bellows to

shorten. The power bellows is prevented from collapsing by a spring inside of it. Extension of this bellows is opposed by a pressure spring, just as downward flexing of the diaphragm in Fig. 36 is opposed.

As the power bellows is extended by increase of pressure from the bulb, the push rod, the valve

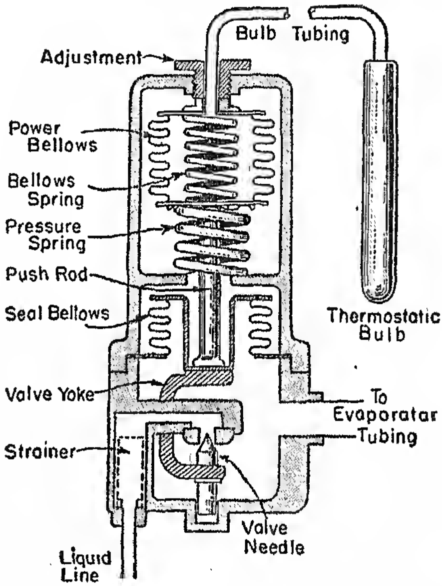

Fig. 37.—A Thermostatic Expansion Valve Employing a Flexible Metallic Bellows.

yoke, and the valve needle are moved downward to open the valve so that liquid refrigerant from the liquid line may enter through the strainer and valve seat to pass as a spray into the evaporator tubing. The space into which the refrigerant liquid enters is separated from the upper part of the valve by the seal bellows. Pressure in this space is the

same as in the evaporator tubing, tending to extend the seal bellows and exert an upward force through the push rod against the power bellows. Thus evaporator pressure tends to shorten the power bellows and close the liquid valve, while bulb pressure tends to lenghten the power bellows and open the valve. When the compressor stops there is an immediate increase of pressure in the evaporator, because there is no longer a suction from the compressor, and the liquid valve closes.

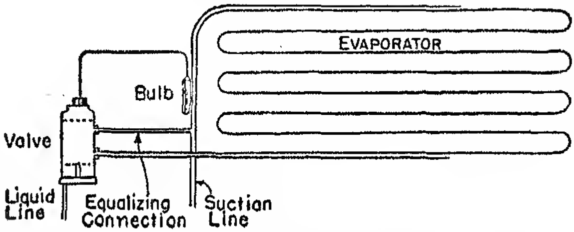

Fig. 38.—An Equalizing Connection May Be Used with an Evaporator Having a Great Length of Tubing.

Equalizing Connection.—In large evaporators, consisting of a long length of tubing between the thermostatic expansion valve and the suction line, there may be a considerable difference between the pressure at the valve or at the entrance to the evaporator and at the suction line end. So that the pressure underneath the diaphragm or power bellows of the valve may be equal to the average of the pressures in the evaporator, an equalizing tubing connection may be run from the suction end of the evaporator to the inside of the valve underneath the diaphragm or the power bellows. Such a connection is shown by Fig. 38.

Automatic Expansion Valve.—Were we to omit the thermostatic bulb from a thermostatic expansion valve, and leave the inside of the power bellows

or the upper side of the diaphragm connected only to surrounding atmospheric air pressure, we would have an automatic expansion valve. The principal working parts of such a valve are illustrated by Fig. 39.

With an automatic expansion valve the pressure underneath the bellows, or underneath a diaphragm in types having a diaphragm, is that at the en-

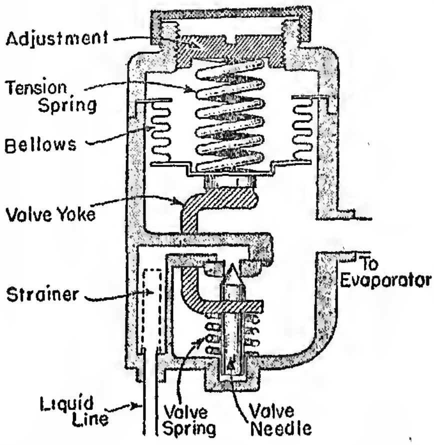

Fig. 39.—The Working Parts of an Automatic Expansion Valve.

trance to the evaporator. The pressure inside the bellows or on top of the diaphragm is atmospheric pressure. Whether the valve is opened or closed depends on the difference between these two pressures, and since atmospheric pressure is fairly constant this valve acts to maintain an equally constant pressure in the evaporator.

The automatic expansion valve, by maintaining a constant evaporating pressure and rate of evaporation, forces the system to operate at a constant heat-absorbing or refrigerating capacity regardless of

whether temperatures around the outside of the evaporator rise or fall. If the temperature rises above a value for which the valve is adjusted, all the liquid refrigerant evaporates long before it reaches the end of the evaporator tubing. If the temperature around the evaporator drops too low, all the liquid is not evaporated and some of it enters the suction line to cause sweating of this line and sometimes of the compressor also. As a consequence of this action, the automatic expansion valve is used only where the required amount of refrigeration remains practically constant, or else where the compressor capacity is being used to the limit and where any additional refrigeration would cause overloading.

The thermostatic expansion valve automatically varies the rate of refrigerant liquid flow and the pressure inside the evaporator to accommodate changes in the required refrigeration, whereas the automatic valve merely maintains a constant evaporating pressure and will not accommodate any great change of load.

Types of Evaporators.—A *flooded evaporator* is an evaporator in which most of the internal space is filled with liquid or with boiling refrigerant, and in which only a small space remains from which vapor is taken to the suction line. Flooded evaporators are used with capillary tubes, high side floats, low side floats and thermostatic expansion valves. They are shown by or might be used with Figs. 30, 31, 33 and 34.

A *dry evaporator* is an evaporator in which practically all of the internal space is filled with refrigerant spray, wet vapor and saturated vapor, with practically no liquid or boiling refrigerant. Dry evaporators are used with high side floats, thermostatic expansion valves and automatic ex-

pansion valves. They are shown by or might be used with Figs. 32, 36, 37, 38 and 39. Liquid refrigerant admitted to the dry evaporator passes through most of the tubing as spray and wet vapor at rather high velocity.

To provide additional superheating and insure against escape of liquid refrigerant into the suction line, dry evaporators used with thermostatic expansion valves often have a few extra turns or coils of tubing on top of the main evaporator and between the thermostatic bulb and the beginning of the suction line.

High-temperature Evaporators.—In some domestic refrigerators there is, in addition to the regular low-temperature evaporator and freezer, an auxiliary or secondary high-temperature evaporator used for cooling compartments in which it is desired to have higher humidity or less drying of foods than when placed in low-temperature spaces.

The principle of one type of high-temperature evaporator is illustrated in Fig. 40. The tubing of the high-temperature evaporator is connected to a tank-type auxiliary condenser, with the refrigerant charge and refrigerant circuit in these parts completely separate from the low-temperature circuit which includes the compressor and the usual condenser for compressed vapor. As refrigerant liquid in the high temperature evaporator changes to vapor and absorbs heat from its compartment, the vapor rises into the auxiliary condenser where it is cooled and condensed to liquid because this auxiliary condenser has attached to it a portion of the regular low-temperature refrigerant tubing. Heat from vapor in the auxiliary condenser is absorbed into the regular refrigerating circuit and finally is discharged as usual through the condenser connected to the compressor. The condensed liquid in

the secondary circuit drops from the auxiliary condenser back to the bottom of the high-temperature evaporator, where it again absorbs heat, vaporizes, and goes once more to the auxiliary condenser.

Oil Return from Evaporators.—Compressor lubricating oil mixes intimately with Freon and with methyl chloride. The refrigerant and oil mixture travels through the liquid line to the evaporator.

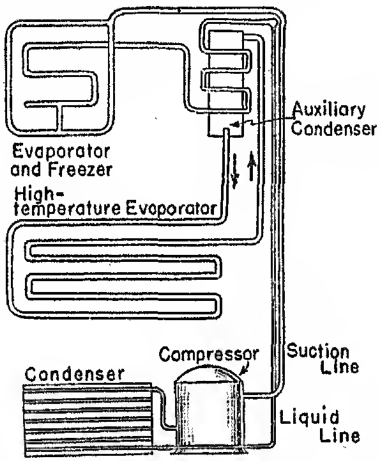

Fig. 40.—A High-temperature Evaporator and Auxiliary Condenser in a Dual Refrigeration System.

As the liquid refrigerant changes to vapor the oil is left as a mist, all of which goes through a dry evaporator and back to the compressor, while in a flooded evaporator some of the oil may float as a thin layer on top of the liquid refrigerant.

Lubricating oil does not mix and remain mixed with sulphur dioxide. However, oil that is forcibly mixed with sulphur dioxide in the compressor goes through the liquid line into the evaporator. The high velocity of spray and vapor through a dry

vapor carries the oil mist through the evaporator and suction line back to the compressor, but in a flooded evaporator the oil separates and forms a layer on top of the liquid refrigerant.

Freon refrigerants average about 60 per cent heavier than lubricating oil, sulphur dioxide is about 50 per cent heavier, and methyl chloride about 10 per cent heavier. Consequently, oil that is not completely mixed will float on top of any of these refrigerant liquids.

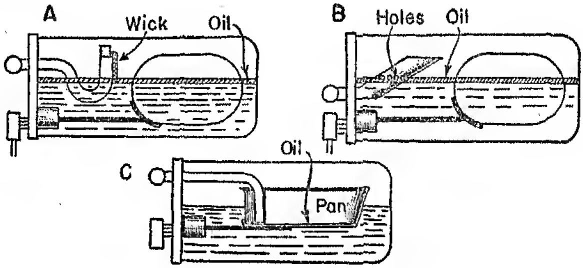

Fig. 41.—Methods of Removing Excess Oil from Flooded Type Evaporators.

In nearly all flooded evaporators, and always in those used with sulphur dioxide, provisions are made to get separated oil out of the evaporator and back into the compressor before the compressor loses enough oil to interfere with effective lubrication. Of the many oil return methods in use, three are illustrated in Fig. 41. At *A* a wick, made of brass mesh, picks up oil from the layer on top of the refrigerant and carries the oil over into the open end of the suction tube from where it is drawn back to the compressor along with the evaporated vapor from the header. At *B* there are numerous small holes in the side of the suction tube, at the level where a layer of oil collects. The oil, with some refrigerant, is drawn through these holes and

returned to the compressor. At *C* the float is an open-topped pan in which the oil vapor collects. The open end of the suction pipe comes close to the bottom of the pan, and when the oil rises to a little height it is sucked into the pipe to be carried through the suction line to the compressor.

Brine Systems.—In some installations the substances to be refrigerated are not cooled by direct contact with the refrigerant evaporator, or by being in an air space cooled by the evaporator, but are indirectly cooled by circulation of a liquid which has been cooled by the refrigerant evaporator. The

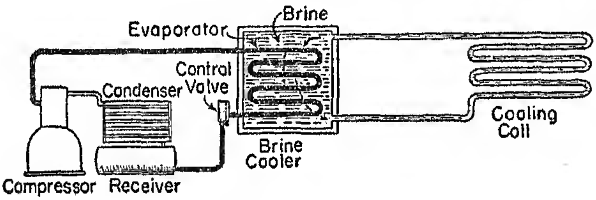

Fig. 42.—An Indirect Cooling System Employing Brine.

principal parts of such a system are shown by Fig. 42. The liquid which is directly cooled by the evaporator, then circulated through a cooling coil where refrigeration is needed, is called the *brine*. If cooling temperatures are to be no lower than 36° F. the brine may be plain water, but for lower temperatures at the cooling coil the brine is a solution of either calcium chloride or sodium chloride, the latter being ordinary salt. The accompanying table lists the approximate pounds per gallon of solution required of either salt. Sodium chloride will not lower the freezing temperature to more than 6° below zero, nor calcium chloride to more than 60° below zero, for with greater concentrations than required for these temperatures the freezing temperature again becomes higher.

SALT BRINE FREEZING TEMPERATURES
(Pounds per Gallon of Solution)

Temperature	Calcium Chloride	Sodium Chloride	Temperature	Calcium Chloride
+30°	0.3	0.2	—10°	3.0
+25°	0.9	0.5	—15°	3.2
+20°	1.3	0.9	—20°	3.4
+15°	1.7	1.2	—30°	3.7
+10°	2.1	1.5	—40°	3.9
+ 5°	2.4	1.8	—50°	4.1
0°	2.6	2.1	—60°	4.2
— 5°	2.8	2.3		

Brine systems may be employed for safety reasons in installations such as air conditioners for hospitals where there must be no possibility of refrigerant vapors entering the chilled air ducts. Brine systems have the advantage of retaining a considerable heat-absorbing capacity in the cold brine after the compressor is stopped.

CHAPTER 4

CONDENSERS AND CONNECTIONS

In a refrigeration system which is operating with a varying load or operating to absorb heat at varying rates the evaporation of liquid refrigerant must proceed at a varying rate which corresponds to the rate of heat absorption. To accommodate the changing demands there must be some excess of liquid refrigerant somewhere in the system. In most commercial systems, and in some domestic refrigerators, there is a receiver to hold the reserve of liquid refrigerant, or else the condenser is so constructed that its lower part holds a supply of liquid. If the system contains a flooded evaporator, this evaporator carries a large reserve of liquid refrigerant. With capillary tubes and other restrictors, and with high side float systems, there is relatively little reserve liquid refrigerant, and the total "charge" of refrigerant in the system must be quite closely adjusted to the rate of refrigeration to be supplied.

The superheated vapor drawn through the suction line into the compressor is at a low temperature, meaning that in a given volume there are relatively few Btu's of heat. As the vapor is compressed, the same quantity of heat that formerly occupied a large space is put into a much smaller space. The greater concentration of heat means a higher temperature. This high-temperature vapor is forced into the condenser.

The vapor in the condenser cools to the temperature which corresponds to its saturated temperature for the pressure existing in the condenser. Heat is being withdrawn through the walls of the condenser and being carried away by air or water circulated

around the outside of the condenser. As the vapor condenses to liquid refrigerant, it gives up latent heat which was absorbed when liquid changed to vapor in the evaporator. In addition to the latent heat picked up in the evaporator, the vapor has been given additional heat by the work done in compressing it. This additional heat amounts to 42.4 Btu's per minute for each horsepower of mechanical power used in operating the compressor.

Air-cooled Condensers.—An air-cooled condenser is one from which heat is removed by air circulated around the outside of the vapor-filled spaces. Many

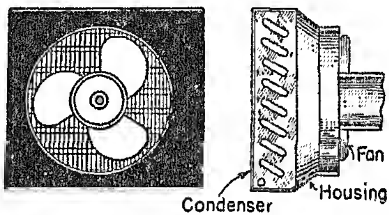

Fig. 43.—A Fan May Drive Air Through an Air-cooled Condenser.

air-cooled condensers consist of finned tubing with air circulation provided by a fan as in Fig. 43. The fan may be on the end of the compressor shaft, may be formed by the spokes of the compressor flywheel, may be on the end of the driving motor shaft, or may be driven by a separate electric motor.

Another type of air-cooled condenser, called a *plate condenser*, is shown by Fig. 44 for one construction. Some of these condensers consist of sheets of thin steel with passages for vapor and liquid between them. The sheets are welded together. Other styles have copper tubing attached to supporting and heat-dissipating sheets of steel. Plate condensers are placed vertically in the backs

of domestic refrigerators, where convection currents of air may flow upward on the condensers.

Finned-tube condensers of large area may be placed at the bottom of an air flue at the back of domestic refrigerators, as shown by Fig. 45. The condenser heats the air and causes it to rise through the flue by convection. No fan is used with these "gravity-flow" condensers.

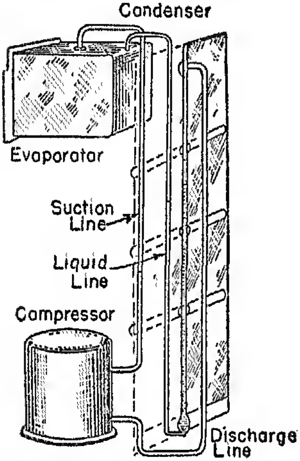

Fig. 44.—A Plate Condenser.

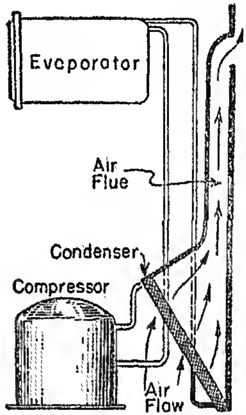

Fig. 45.—A Gravity-flow Condenser.

Water-cooled Condensers.—Most commercial refrigeration systems include water-cooled condensers rather than air-cooled types. Fig. 46 illustrates one of the simplest of the water-cooled types, called a *shell and coil* condenser. Refrigerant vapor from the compressor enters a cylindrical drum in which is a coil of tubing through which cooling water flows. The lowered temperature resulting from heat removed with the water causes condensation of the vapor. The condensed liquid refrigerant collects in

the lower part of the condenser, which thus acts as a receiver. The liquid line leads from this liquid-filled portion of the condenser. Detachable heads on the ends of the condenser allow removal of the coil when this becomes necessary during service operations.

The shell and coil condenser, shown in a horizontal position by Fig. 46, may be constructed also in a vertical type. Compressed vapor then enters at the top of the vertical cylindrical shell, condenses, and collects as liquid in the lower end of the shell.

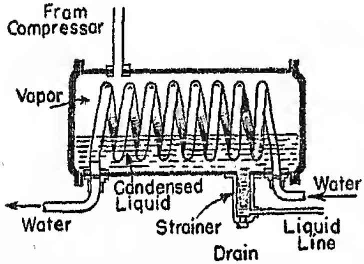

Fig. 46.—A Shell-and-Coil Condenser.

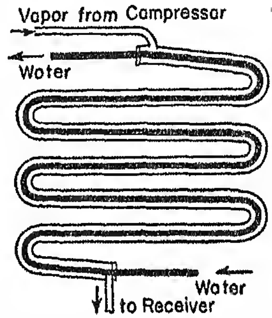

Fig. 47.—A Double-tube Condenser.

Fig. 47 illustrates the principle of a *double tube* water-cooled condenser. Such condensers consist of long lengths of coiled tubing having one tube within another tube. Cooling water flows through the inner tube, and condensing vapor through the outer tube. Because of the limited capacity of the tubing, this style of condenser usually is used with a separate receiver.

Fig. 48 shows the construction principle of a *shell and tube* water-cooled condenser. This type consists of a cylindrical shell or drum between the ends of which are many straight tubes through

which a flow of cooling water is maintained. Compressed vapor enters the top of the shell, condenses in the space containing the water tubes, and either collects as liquid in the lower part of the shell, which then acts as a receiver, or else passes to a separate receiver of greater capacity.

By means of partitions in headers on the ends of the shell, water is caused to flow back and forth through alternate groups of water tubes. The partitions are arranged so that there is the same number

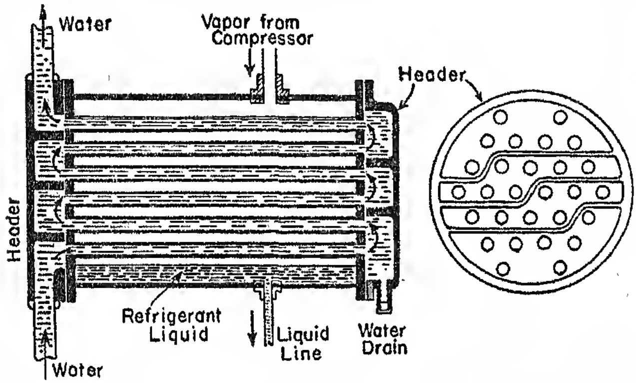

Fig. 48.—The Construction of a Shell-and-Tube Condenser and a Typical Header.

of tubes in each "pass" from one end to the other of the shell, the plan being somewhat as illustrated at the right-hand side of the illustration. Water may pass back and forth through the length of the condenser various numbers of times. Fig. 48 shows three passages in each direction. Fig. 49 shows one passage in each direction, also two in each direction.

Shell and tube condensers may be constructed as in Fig. 50, with a number of U-shaped tubes or looped tubes fastened into a single tube sheet at one

end of the condenser shell. The tube sheet with all the tubes may be removed from the condenser as a unit when servicing is required.

In Figs. 46, 47 and 48 it is clearly indicated that cooling water enters the end of the condenser from which condensed refrigerant leaves the condenser, and that water leaves from the end at which hot compressed vapor enters. Water and refrigerant flow in opposite directions through the condenser.

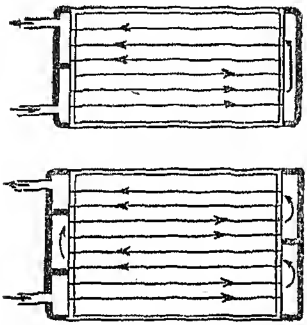

Fig. 49.—Water May Pass Various Numbers of Times Through Shell-and-Tube Condensers.

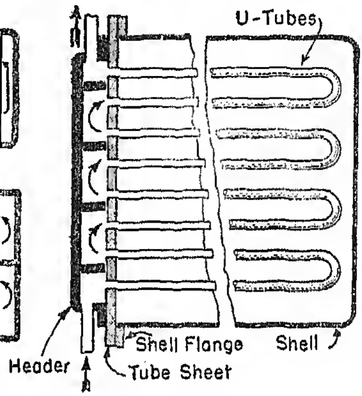

Fig. 50.—A Shell-and-Tube Condenser with U-tubes and a Single Header.

This is the *counterflow* principle of circulation. The coolest water (entering water) acts on the coolest (condensed) refrigerant, while the hottest refrigerant (vaporous) is acted on by the warmest water (leaving water). With counterflow of water and refrigerant the average temperature difference between the two is most effective for removal of heat from the refrigerant. There is a better average effect throughout the condenser than would exist with water and refrigerant flowing the same direction.

At the lowest point of a condenser or receiver there frequently is a refrigerant *drain valve* through which refrigerant may be removed when repairs are necessary or when the system has been given an overcharge of refrigerant.

At the top of the condenser or receiver, or at the highest point of the discharge line from compressor to condenser there is a *purge valve* or some other connection which may be opened to remove air or other non-condensible gases from the system when they have entered during service operations or at any other time.

Receivers in systems using air-cooled condensers sometimes have a *fusible plug* in the vapor-filled portion of the shell. Such a plug usually consists of a brass shell. In the opening through the shell is a metal that melts at a temperature corresponding to a dangerously high pressure in the high side, thus relieving the pressure. The outlet for the plug is connected through a vent tubing to outdoors or to some location permitted by local codes for refrigeration installations.

Water-regulating Valves.—Fig. 51 shows the principal parts of a refrigeration system in which the condenser is of the water-cooled type. Between the cooling water supply and the water inlet connection to the condenser is a water regulating valve from which a length of tubing leads to the high side of the system. This valve varies the rate of water flow in accordance with pressure in the high side; increasing the rate of water flow as high-side pressure rises, and lessening the water flow as high-side pressure drops. Thus the effect of the regulating valve is to maintain a nearly constant high-side pressure or condensing pressure, this pressure being that for which the regulating valve is adjusted.

Condensing pressures and temperatures change together, and in the same direction. Here, for example, are some condensing pressures and accompanying temperatures for Freon-12 refrigerant; the pressures being in pounds per square inch and the temperature in degrees Fahrenheit.

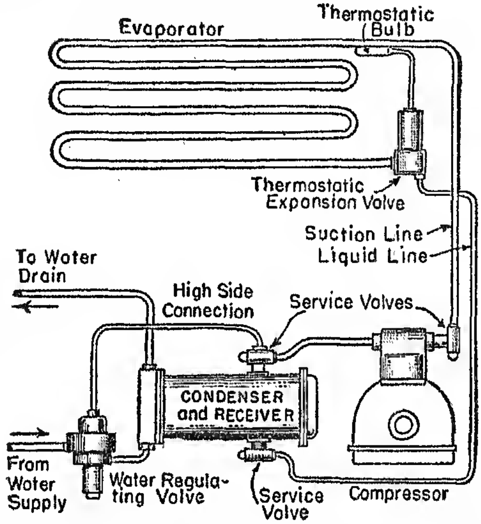

Fig. 51.—Connections for Controlling the Rate of Water Flow with a Water Regulating Valve.

85 lbs.	70.2°	110 lbs.	87.4°	135 lbs.	101.9°
90 lbs.	73.9°	115 lbs.	90.3°	140 lbs.	104.5°
95 lbs.	77.6°	120 lbs.	93.4°	145 lbs.	107.0°
100 lbs.	80.9°	125 lbs.	96.2°	150 lbs.	109.5°
105 lbs.	84.2°	130 lbs.	99.1°	155 lbs.	112.0°

It is apparent that we may change the condensing pressure by changing the temperature in which the vapor condenses. The condensing temperature may be lowered, and the pressure lowered, by allowing more water to flow through the condenser; while

temperature and pressure will be raised by decreasing the rate of flow of cooling water. The lower the condensing pressure the less power will be required to run the compressor, but the more water will be needed for cooling. Operation is desired at a pressure where the combined cost for driving power and cooling water is the least.

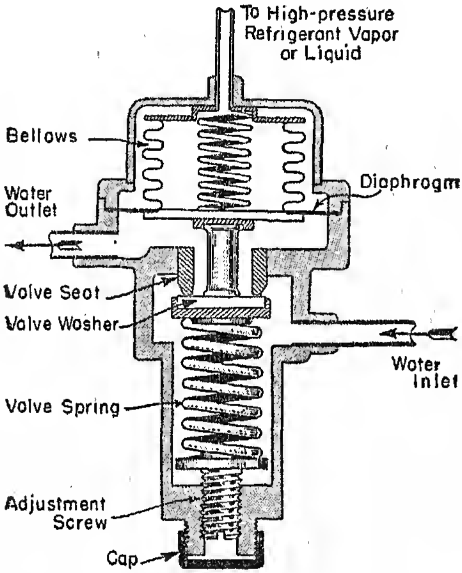

Fig. 52.—The Principal Parts of a Water Regulating Valve.

The principal operating parts of one style of water regulating valve are shown by Fig. 52. Cooling water enters the inlet connection. If the valve washer is pressed down, away from its seat, the water flows through the valve and leaves by the outlet connection. Pressure from the high side of the apparatus reaches the interior of the bellows through the tubing connection. This pressure tends

to extend the bellows against the tension of the valve spring and to open the valve. Whether the valve is open or closed, and the degree to which it is opened, depend on the difference between the high-side pressure and the tension of the spring. Spring tension is adjustable, allowing the valve to be set for a rate of water flow that maintains any desired high-side pressure within normal operating limits. The flexible diaphragm of Fig. 52 maintains a water-tight seal in case of bellows leakage.

Water-regulating valves are made in many different designs, but the operating principle is the same in all. Some have flexible diaphragms instead of the bellows shown in Fig. 52. The valve usually is placed between the water supply line and the condenser inlet, but sometimes is between the condenser and the water drain connection. The valve bellows, or diaphragm space, may be connected to the compressor discharge line, to the head of the compressor, or to the top of the condenser, so that it receives high-pressure vapor. The bellows, or diaphragm, frequently is connected to the liquid line or to some other part containing high-pressure refrigerant liquid instead of high-pressure vapor.

When the compressor is stopped, pressure gradually decreases in the high side and allows the valve to close and shut off flow of water. As soon as the compressor is again started, the rise of high-side pressure opens the valve and permits water flow to resume.

When the compressor head, or the head and part of the cylinder walls, are cooled by water, the flow of cooling water ordinarily is controlled by the same regulating valve that handles the condenser. Part of the water leaving the condenser may be diverted through the compressor by a bypass valve such as shown by Fig. 53. This valve is adjustable so that

any portion of the condenser outlet water, or all of it, may be sent through the water jackets of the compressor.

The greater the rise of temperature in the water as it passes through the condenser the more heat it will absorb, because heat absorption by water is at the rate of one Btu per pound per degree of temperature rise. The rise usually is between 10 and 20 degrees. The approximate required flow, in gallons per minute, is as follows:

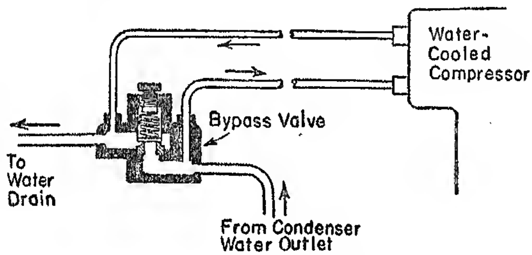

Fig. 53.—An Adjustable Bypass Regulates Water Flow to a Water-cooled Compressor.

$$\text{Gallons per minute} = \frac{\text{heat absorbed, Btu's per minute}}{7 \times \text{degrees temperature rise}}$$

Shut-off Valves.—Shut-off valves or service valves are inserted in the tubing connections between various parts of the refrigeration apparatus. These valves permit removal of the compressor for servicing while the refrigerant is retained in the remaining parts, they permit collecting and retaining the refrigerant in the condenser and receiver while service operations are performed on other parts, and some types of valves allow measurement of pressures in either the low side or high side of the system.

Fig. 54 shows the usual locations of shut-off valves. In practically every installation there will be a low-side shut-off valve where the suction line enters the compressor, and a high-side shut-off valve where the discharge line leaves the compressor. In many installations having the condenser and receiver separate there will be a shut-off valve between these two parts. In the majority of installations there will be a shut-off valve where the liquid line leaves either the condenser or the receiver.

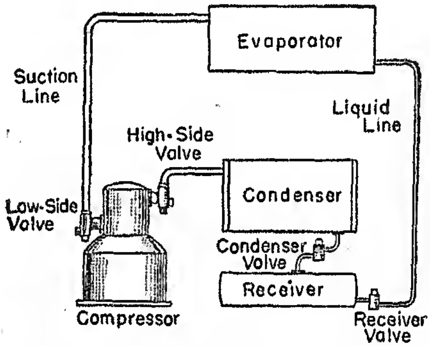

Fig. 54.—Locations of Shut-off Valves or Service Valves between the Parts of a Refrigeration System.

Shut-off valves at the entrance to the liquid line, also those between separate condensers and receivers when used, usually are simple one-way valves which may be either opened or closed to allow or prevent flow through a single line of tubing. Shut-off valves used at the low-side and high-side connections to the compressor nearly always are three-way types.

Fig. 55 shows the construction principle and operation of one style of three-way valve. Other styles differ in construction, but operate similarly.

The three-way valve includes a double-ended needle which may be screwed against either one of two opposite seats, or else left between the seats so that it makes contact with neither. The opening marked *A* connects to the compressor on either the suction or discharge side, depending on where the valve is mounted. The opening marked *B* connects with either the suction line on the low side or with the discharge line to the condenser on the high side. Opening *C* may be used for connection of a pressure

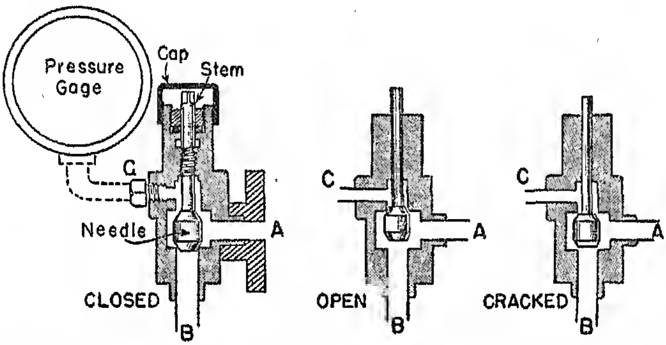

Fig. 55.—The Positions of the Needle in a Three-way Shut-off Valve or Service Valve.

gage to measure pressures on either the low side or high side of the apparatus while the compressor is running or is idle. This opening is closed by a tight plug except while it is being used during service operations. In addition to being used as a pressure gage connection, opening *C* may be opened to allow escape of air, refrigerant liquid, or refrigerant vapor, depending on where the valve is located in the system, and it may be used also for adding refrigerant to the system.

In the *closed* position the line at *B* is shut off from *A* and *C*, and *C* ordinarily is closed by its plug.

In the *open* position of the valve there is free passage between connections *A* and *B*, this being the normal operating position. If the valve is *cracked*, by leaving the needle in between the two seats, openings *A*, *B* and *C* are connected together. Then a gage connected at *C* will measure either low side pressure or high side pressure, depending on valve location, while the compressor is operating. For such pressure measurements the valve first is opened all the way, then "cracked" just enough to allow a steady reading on the gage.

Heat Exchangers.—The lower the temperature of the refrigerant liquid when it enters the evaporator the less refrigeration will have to be wasted in cooling it to the temperature of evaporation. The higher the temperature of the refrigerant vapor when it enters the suction line the less is the likelihood of sweating and frosting. To cool the liquid, which often leaves the receiver at a temperature of 70 to 80 degrees, and to warm the vapor, which may leave the evaporator at a temperature of 30 to 40 degrees, the two are brought together in a heat exchanger.

As shown by Fig. 56, the heat exchanger is placed close to the evaporator. The exchanger may consist of a cylinder through which suction vapor passes and makes contact with a coil carrying the liquid refrigerant, it may consist of a double-walled tube with suction vapor flowing through the inner tube and liquid through the outer shell, or of any other arrangement in which heat from the warm liquid may pass into the cool vapor.

Heat exchangers of the general types illustrated in Fig. 56 generally are used in commercial installations where efficiency and power savings are important. A similar effect is secured in many domestic refrigerators by running the liquid and suction

lines together for some distance, often by soldering them together. Such arrangements are indicated in Figs. 31 and 40.

Strainers and Filters.—Within all refrigeration systems there may be small metal chips from machine work, particles from sawing and filing of tubing, scale from soldering and welding, and a variety of other foreign matter. Any such dirt is likely to clog the small openings in expansion valves and other needle-type valves, to score valve seats in the compressor, and to cause binding of closely

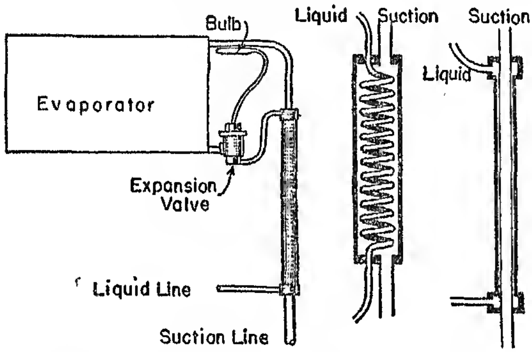

Fig. 56.—Heat Exchangers and How They Are Connected.

fitted elements. Freon refrigerants, especially, have the property of loosening and carrying through the system all manner of particles which may cause trouble.

To prevent trouble, so far as may be possible, strainers or filters may be placed in tubing lines ahead of any types of valves in the refrigeration system. They are used between the condenser or receiver outlet and the refrigerant control valve or restrictor for the evaporator, and in many installations are placed also in the suction line just ahead of the compressor. Evaporator feed valves usually

have their own built-in filters, but additional units may be used at the receiver end of the liquid line.

Fig. 57 illustrates constructions which are typical of strainers or filters used in suction lines and in liquid lines. All of them contain one or more fine-mesh wire screens. Some liquid line filters have, in addition to the wire screens, porous pads of felt, metal wool, asbestos cloth, or similar substances held between two screens. These pads catch and

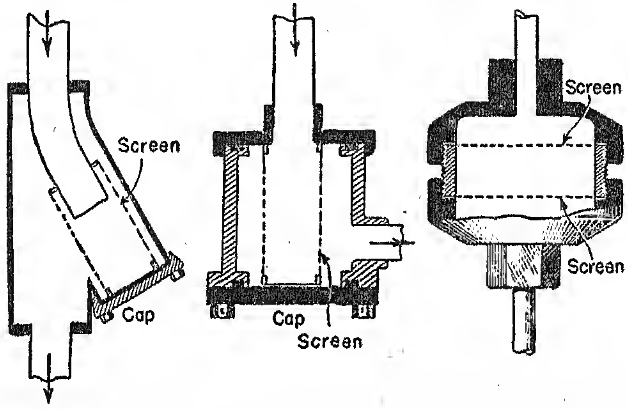

Fig. 57.—Strainers or Filters Used in Liquid Lines and Suction Lines.

hold particles that pass through the mesh screens. In some installations a shut-off valve or service valve is placed on each end of the strainer to allow removal and cleaning of the screen without losing refrigerant from or allowing entrance of air to other parts of the system.

Water strainers frequently are fitted ahead of water regulating valves to keep out scale and dirt that comes from most public water supplies. Oil strainers are used at the inlets for pumps in forced feed compressor lubrication systems.

CHAPTER 5

TEMPERATURE AND PRESSURE CONTROLS

Substances are refrigerated or cooled when they are in contact with or are close to anything which is at a lower temperature, for heat then will flow from the higher to the lower temperatures. In most refrigerating systems, air is cooled by an evaporator and then the air is circulated around the substances to be refrigerated. In some systems heat is transferred by circulating water or brine. The heat transfer medium, which may be air, water, or brine, must be at a lower temperature than that of the substances refrigerated, and the evaporator must be at a lower temperature than that of the circulating air, water or brine.

The rate at which refrigeration takes place depends on the difference between the temperature of the substance being cooled and the temperature inside the evaporator. The evaporator temperature always must be considerably lower than that of the refrigerated substances. The lowest refrigerating temperature will correspond to the lowest temperature in the evaporator, and the highest refrigerating temperature will correspond to the highest temperature in the evaporator, although the evaporator temperatures always will be much lower than those of the refrigerated articles.

Refrigeration temperatures usually are controlled by starting the compressor when the temperature rises to the maximum desired value, running the compressor until the temperature has been lowered to the minimum desired value, then stopping the compressor. A compressor driven by an electric

motor is started and stopped by starting and stopping the motor. Consequently, the temperature control will be some form of electric switch that closes to start the motor and compressor at a higher temperature, and that opens to stop the motor and compressor at a lower temperature.

The temperature produced within the evaporator varies with the pressure produced within the evaporator. Since the temperatures outside and around the evaporator must vary with the internal temperatures, we may say that temperatures outside and around the evaporator must vary with pressures inside the evaporator.

It becomes apparent that we may control our refrigerating temperatures in either of two principal ways. First, the electric switch for motor and compressor operation may be actuated directly from temperature at the evaporator or in the space being cooled. Second, the electric switch may be actuated by pressure inside the evaporator. The relations between evaporating temperature and pressures for the three common refrigerants are shown by the accompanying list.

EVAPORATING TEMPERATURES AND PRESSURES

Temperature, F.	Pressures, Lbs. Per Sq. In. Freon-12	Methyl Chloride	Sulphur Dioxide
—20°	15.3	11.7	5.9
—10°	19.2	14.9	7.9
0	23.9	18.8	10.4
+10°	29.4	23.3	13.4
+20°	35.8	28.8	17.2
+30°	43.2	35.2	21.7
+40°	51.7	42.6	27.1

Control by Low Side Pressure.—Fig. 58 illustrates the principle of refrigerating temperature control

through operating the compressor in accordance with changes of pressure in the evaporator or in the low side of the system, this usually being called a *pressure control.*

The compressor is belt-driven from an electric motor. The motor is connected to the electric power line through contacts in the control unit. These contacts are closed and opened by expansion and

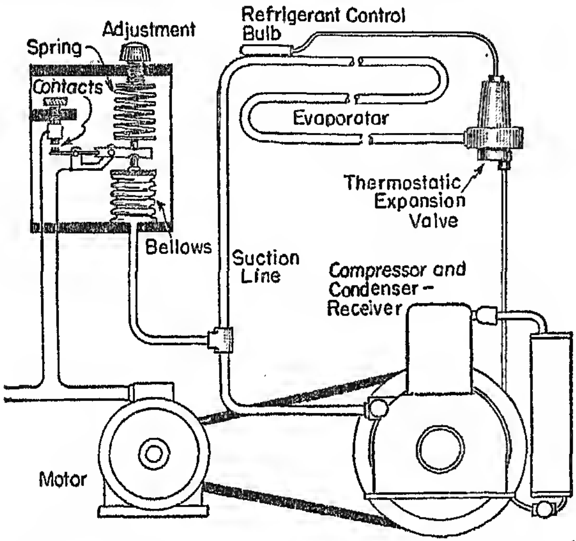

Fig. 58.—The Principle of a Pressure Control for Starting and Stopping the Compressor.

contraction of a bellows whose expansion is opposed by a coiled spring. The inside of the bellows is connected through tubing to the suction line or to anywhere in the low side.

As the evaporator and low side become warmer there is a rise of refrigerant vapor pressure which expands the control bellows against the spring ten-

sion. At a vapor pressure depending on the bellows force and the opposing spring tension, or on the difference between them, the switch contacts will be closed to start the motor and compressor. Compressor operation will decrease the low side pressure, cause evaporation and heat absorption to take place, and refrigerating temperature will drop. The decreased low side pressure allows the bellows to shorten. After a certain decrease of pressure, and temperature, the switch contacts will be opened to stop the motor and compressor. Then temperatures will rise slowly in the refrigerated space and evaporator until the accompanying increase of low side pressure again closes the switch contacts and starts the compressor.

Operation of any pressure control for temperature depends on low side pressures that rise and fall with changes of temperature. Consequently, a pressure control for temperature cannot be used with an automatic expansion valve or with any other refrigerant control device which maintains a practically constant evaporating pressure in the low side. With a refrigerant control maintaining constant low-side pressure there would be no changes of pressure to operate the temperature control.

Thermostatic Temperature Control.—Instead of connecting the interior of the switch-operating bellows to the vapor space of the low side it may be connected, as in Fig. 59, to a thermostatic bulb within which is refrigerant vapor or liquid and vapor. Vapor pressure in the bulb and the interior of the switch bellows then will increase with rise of temperature at the bulb, and will decrease with fall of temperature at the bulb. The switch control for the compressor motor now depends directly and solely on changes of temperature at the thermostatic bulb, and is entirely independent of changes of low

side pressure so far as actual operation is concerned.

The construction and adjustment of the switch control mechanism for use with a thermostatic temperature bulb usually is identical with a similar

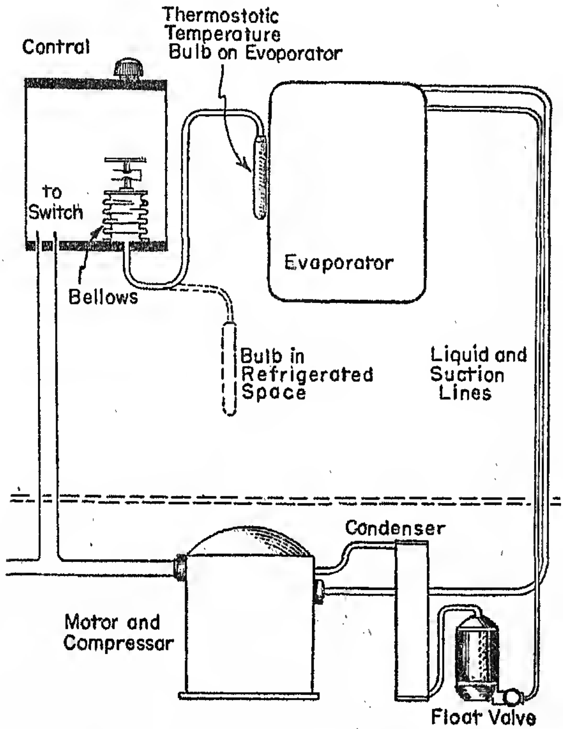

Fig. 59.—A Thermostatic Temperature Control Is Operated by Temperature at a Thermostatic Bulb.

type used for pressure control. The only difference is in the addition of the thermostatic bulb and its connecting tubing.

The thermostatic temperature control may be used in connection with any type of refrigerant

control, since it does not depend on conditions of the refrigerant vapor or liquid within the evaporator, but only on changes of temperature around the control bulb.

Thermostatic Bulbs.—Fig. 60 illustrates approximate differences in size of various thermostatic temperature bulbs. A bulb to be used in an air space usually is larger than one which is to be inserted in a refrigerated liquid, this because the rate of heat transfer from air to metal is much less than from liquid to metal.

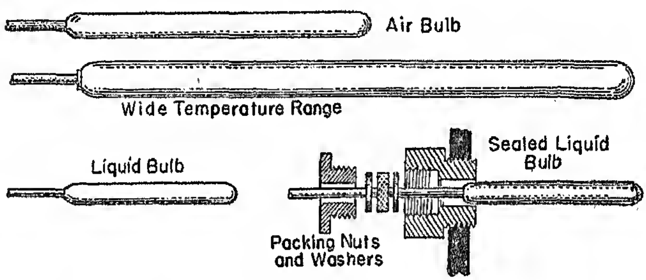

Fig. 60.—Size of the Thermostatic Bulb Depends on Where It Is to Be Used.

Very large thermostatic bulbs are used when the refrigerating apparatus may have to operate throughout a wide range of temperature, with which the temperature at the switch bellows may be much higher, or sometimes lower, than that around the control bulb. Using a large bulb containing a large quantity of liquid and vapor insures that vapor pressures affecting the control switch operation will be those corresponding to bulb temperature rather than to bellows temperature.

Bulbs for insertion into closed or sealed spaces containing a liquid whose temperature is to be the controlling factor may be mounted with a threaded shell into which screws a packing and retaining nut.

Toggle Actions for Switches.—In the simple switch arrangement of Fig. 58 the switch contacts would open and close slowly and gradually as the bellows shortened and lengthened with changes of pressure. When an electric switch controlling any considerable amount of electric power is opened slowly there is a tendency for electricity to continue flowing across the small gap that exists just after the contacts separate. This flow, called arcing, would rapidly burn and pit the contacts. To maintain the switch contacts in good condition it is necessary that there be a quick break, or a snap action, which almost instantly extinguishes the arc by suddenly lengthening the gap.

Quick breaks of refrigerating control switches are secured in various ways. The three most common methods are by means of a toggle action, by means of a small permanent magnet, and by means of a mercury switch. One method by which a toggle action may be utilized is illustrated by Fig. 61. As the bellows expands it raises lever *A* which is pivoted at its left-hand end and is attached to the tension spring at its right-hand end. The tension spring opposes bellows expansion. Lever *A* raises plunger *B* on which is a fixed collar *C* and an adjustable collar *D*. Between the collars rides lever *E*, pivoted toward the right, and at its extreme right-hand end carrying the contact bar which comes down onto the two contacts to complete the electric circuit for starting the compressor motor.

A fork on the left-hand end of lever *E* engages a pin on lever *F*. Between the other end of lever *F* and the right-hand end of lever *E* is the toggle spring. With the contacts open, as shown, the toggle spring acts to hold them open and to hold lever *E* down against fixed collar *C*. As expansion of the bellows raises lever *E* the toggle spring is stretched.

When expansion of the bellows raises lever *E* to a point where its forked end and the pin on lever *F* come on a line between the pivots for levers *E* and *F* we have a condition of dead center. The least additional rise of lever *E* carries its fork beyond the dead center and the pull of the toggle spring snaps levers *E* and *F* into the positions shown in Fig. 62, bringing the contact bar down onto the

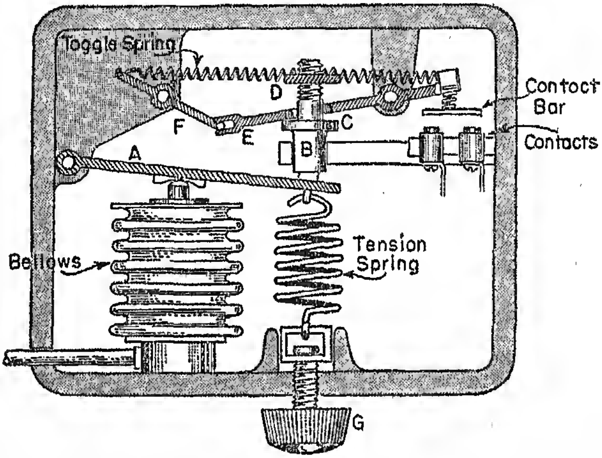

Fig. 61.—A Toggle Mechanism to Cause Snap Action of the Switch Contacts.

contacts, and bringing lever *E* against the upper adjustable collar *D* on plunger *B*.

With decrease of pressure inside the bellows the tension spring will pull down on lever *A* and plunger *B*, thus bringing levers *E* and *F* back toward the dead center position. The contact bar will remain on the two contacts until the levers snap past the dead center point under the influence of the toggle spring. At this instant there will be a

quick break at the contacts and the compressor motor will be stopped.

There is great variety in the mechanical construction of toggle-type switches or temperature controls. However, all contain a bellows or an equivalent diaphragm, a spring or springs which oppose expansion of the bellows or diaphragm, levers which snap past a dead center, and a spring or springs which accomplish the snap action. The operation of any type is quite apparent upon examination, or at least upon movement or attempted movement of the lever which is acted on by the bellows or diaphragm.

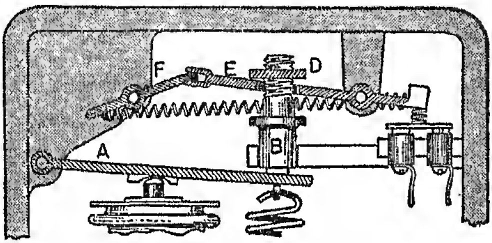

Fig. 62.—The Snap-action Switch with Its Contacts Closed.

Permanent Magnet Snap Action.—If you hold a permanent magnet stationary and slowly move toward it a piece of steel there will at first be little attractive force. But when the steel comes within a small fraction of an inch of the magnet there will be a strong pull tending to bring the two together. To then separate the steel from the magnet takes quite a bit of force, but the instant that there is a small space between the two only a little attractive force remains. This action of a permanent magnet on a piece of steel is utilized in quick-acting control switches.

In the control switch of Fig. 63 the movable contact of a pair is carried by a steel blade which is

pivoted at its extreme right-hand end. The left-hand end of the blade is close to the poles of a permanent magnet, but is held away from the magnet by a light spring. As the blade is moved still closer to the magnet the attraction finally overcomes the effect of the spring and the contacts are closed. As force from the expanding bellows acts to separate the switch contacts, this force is opposed by the attraction of the permanent magnet for the

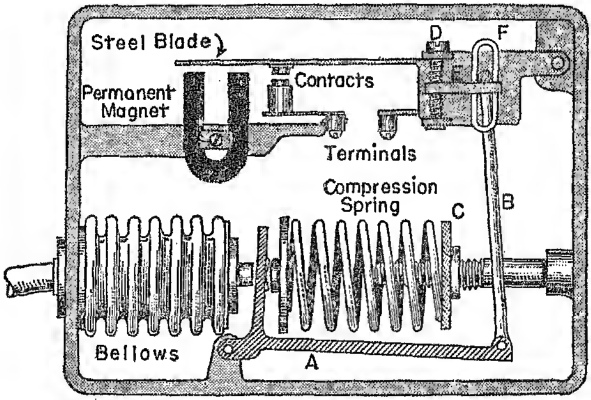

Fig. 63.—Snap-action Obtained with a Permanent Magnet.

steel blade. Finally the bellows force overcomes the magnetic attraction and the contacts are opened with a jerk.

Expansion of the bellows in Fig. 63 is opposed by the large compression spring. Between the bellows and compression spring is an extension of lever *A*. Expansion of the bellows, with rising pressure and temperature, moves lever *A* to pull down on rod *B*, pull down on the steel blade, and close the switch contacts. The contacts are opened when the bellows shortens, allowing the compression spring to raise lever *A* and rod *B*.

Mercury Switch.—The operating principle of a mercury switch is shown by Fig. 64. Inside a glass or ceramic tube is a pool of the liquid metal, mercury. At one end of the tube are the ends of wires which form a part of the motor control circuit. When the switch is tilted so that the mercury is at the end of the tube opposite the wire ends the switch is open. As the switch is tilted the other direction the mercury flows around the wire ends and the switch is closed, with the motor control circuit completed through the mercury.

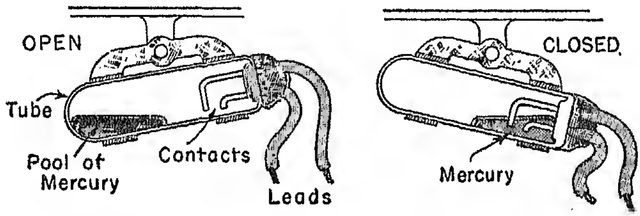

Fig. 64.—How the Mercury Switch Closes an Electric Circuit.

As a mercury switch is slowly moved from the closed to the open position the mercury flows suddenly from one end to the other just as the tube passes the horizontal position, thus effecting a quick break of the electric circuit. The inside of the switch tube is highly evacuated so that there is no oxygen to allow flashing or arcing as the electric circuit is broken inside the tube. A mercury switch incorporated in a refrigeration pressure or temperature control is shown by Fig. 65.

Range and Differential.—Supposing we wish to maintain an evaporator at an average temperature of 25°. If the switch which controls operation of the compressor motor were to act at exactly 25° the compressor would be started at this temperature,

but within a very few moments the temperature would have dropped slightly below 25° and the compressor would be stopped. The result would be starting and stopping of the compressor a great

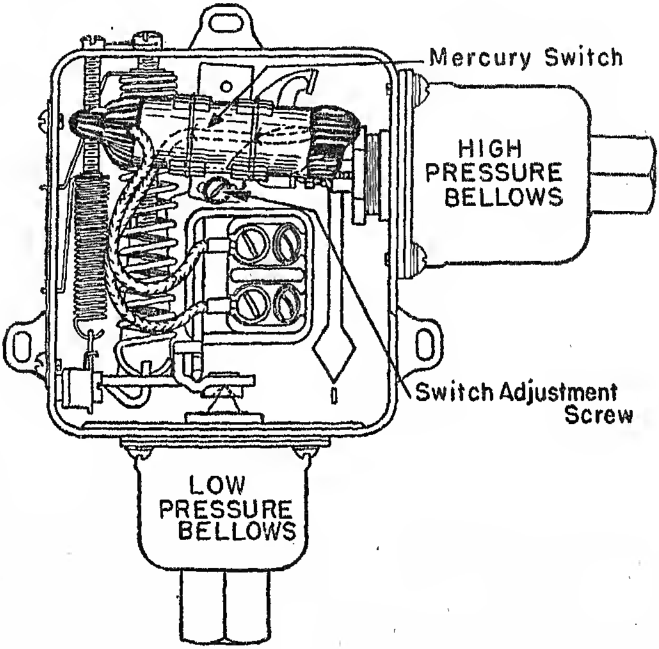

Fig. 65.—A Temperature Control Incorporating a Mercury Switch (Minneapolis-Honeywell Type).

number of times every hour, causing needless wear and tear on all the mechanism.

To maintain the average temperature of 25° we might start the compressor only when the temperature rises to 30°, then allow refrigeration to continue until the temperature drops to 20° before stopping the compressor. Such action is shown at *A* in Fig. 66. The starting temperature, called the

cut-in temperature, is 30°. The stopping temperature, called the *cut-out* temperature, is 20°. The difference between cut-in and cut-out is 10°. This difference is called the *differential.* The *range* of temperature is from 20° to 30°.

At *B* in Fig. 66 the cut-in is at 18° and the cut-out is at 8°. The difference, or the differential, still is 10°, but now the range is from 8° to 18°. At *C* we still have a differential of 10°, with a range of 25° to 35°.

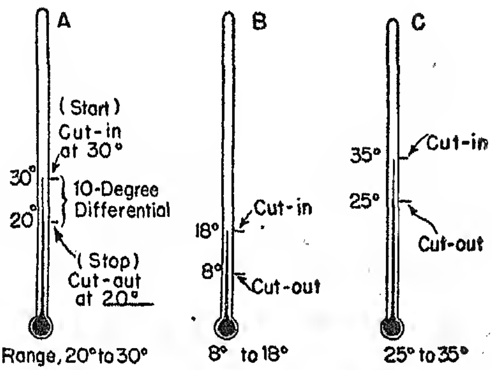

Fig. 66.—Cut-in, Cut-out, Range, and Differential for a Temperature Control.

The range determines the average refrigerating temperature, it determines the highest temperature allowed before cooling commences, and it determines the lowest temperature produced before cooling is stopped.

The differential determines the length of time that the compressor operates each time it is started, because the compressor must run for long enough to lower the temperature by the amount of the differential. The differential determines also the length of the periods in which the compressor is idle, be-

cause the compressor will remain idle while temperature rises by the amount of the differential. Although we have been speaking of differentials and ranges measured in degrees of temperature, they might be specified equally well in vapor pressures. Then we would have differentials of so many pounds of pressure, and ranges between certain specified pounds of pressure.

The adjustment for the range alters the tension or compression of the spring that opposes expansion of the bellows or diaphragm. In Fig. 61 the range adjustment is by means of the knob *G* which turns a screw to increase or decrease the tension of the spring that opposes bellows expansion. In Fig. 63 the range is adjusted or altered by turning knurled nut *C* to increase or decrease the compression of the spring that opposes bellows expansion. In Fig. 65 the range is changed by adjusting the tension of the larger coiled spring that is connected to the lever actuated by the bellows.

Increasing the tension or compression of the spring that opposes bellows expansion requires that the bellows exert greater pressure to close the switch, so such an increase of tension or compression raises the temperature range or pressure range. Decreasing the spring tension or compression lowers the range of temperature or pressure.

The adjustment for the differential usually changes the amount by which the bellows must expand before it can close the switch contacts after they have been opened, and changes the amount by which the bellows must contract before opening the switch contacts after they have been closed.

In Fig. 61 the differential is adjusted or altered by turning the knurled collar *D*, which changes the distance that lever *E* moves between collars *C* and *D*, and thus changes the distance that bellows action

must move lever *E* before it reaches dead center and snaps to its opposite position. In Fig. 63 the differential is changed by turning screw *D*, which raises or lowers bar *E*, and changes the distance through which the end of rod *B* must move in slot *F* to close or open the switch contacts. In Fig. 65 the differential is adjusted by changing the tension of the smaller coiled spring, which raises or lowers the cut-in point with reference to the cut-out point.

Adjustment of the range commonly has little or no effect on the amount of differential. That is, as in Fig. 66, the range may be raised or lowered

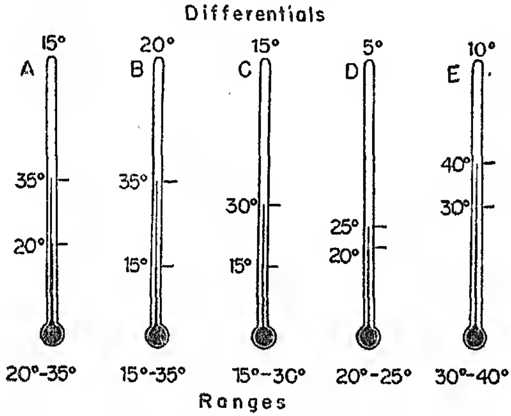

Fig. 67.—Altering the Cut-in and Cut-out Changes the Range and the Differential.

while maintaining the same differential. In some mechanisms the range adjustment raises or lowers the cut-out temperature or pressure, and a separate differential adjustment determines how far the cut-in point is above the cut-out which has been set by the range adjustment. In other mechanisms there are separate adjustments for cut-in and for cut-out, neither one being strictly a range adjust-

ment or a differential adjustment, but both affecting the range and the differential.

In Fig. 67 we begin at *A* with cut-in at 35°, cut-out at 20°, and a differential of 15°. At *B* the cut-out point is lowered, at *C* the cut-in point is lowered, at *D* the cut-in is lowered and the cut-out raised, and at *E* both cut-in and cut-out are raised. The resulting ranges and differentials are shown.

Domestic Controls.—The thermostatic temperature control with a temperature bulb, Fig. 59, is used more generally for domestic refrigerators than is the pressure type of control. The control unit for a domestic refrigerator usually has an exposed and accessible knob or pointer and dial for changing the range adjustment, and a concealed adjustment for differential. There either is a separate off-on switch for placing the refrigerator out of service or in service, or else this switch is combined with the temperature (range) adjusting device. Sometimes there is a "re-set" button for closing an electrical overload cutout which acts to open the motor circuit when the system is electrically or mechanically overloaded in any way.

Control units for domestic refrigerators may have a "defrosting" switch or button which permits a temperature higher than normal for a period in which ice and heavy frost accumulated on the exterior of the evaporator melt away. The ice or frost is due to condensation of water vapor from air which comes in contact with the evaporator. A defrosting control may operate to raise the cut-in temperature during one or more cycles of compressor operation. The cut-in temperature may be raised by temporarily increasing the tension or compression of the spring that opposes bellows expansion, thus requiring a higher pressure and temperature before the switch is closed.

High-pressure Cutout.—In nearly all refrigerating systems having water-cooled condensers, and in many having air-cooled condensers, there is a high-pressure cutout switch that opens the motor control circuit and stops the compressor in case the high-

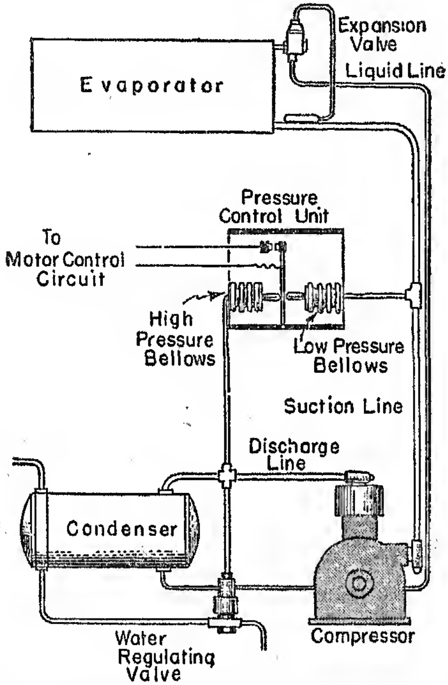

Fig. 68.—The High-pressure Cutout Stops the Compressor When High Side Pressure Becomes Excessive.

side pressure exceeds a safe operating limit. The high-pressure cutout is a bellows-actuated or a diaphragm-actuated switch constructed either as part of a pressure control for regulating low side pressures and evaporating temperatures, or else as a

separate and independent unit for use with thermostatic temperature control of compressor operation.

Fig. 68 shows the relation of a combined high-pressure cutout and low-side pressure and temperature control to other parts of a typical refrigeration system. The diagram of the pressure control unit illustrates the basic principle of operation, but not the construction. Fig. 65 shows one style of low-side pressure control with which is combined the extra bellows required for a high-pressure cutout.

The low pressure bellows is connected to the suction line or to any portion of the low side, as was shown in Fig. 58. The bellows for the high-pressure cutout is connected usually to the discharge line between compressor and condenser, but sometimes to the liquid line in which also exists the high-side pressure. The low-pressure bellows acts to close the motor switch with increase of low side pressure and to open the switch with decrease of low side pressure, as has already been explained in detail. The high-pressure bellows acts oppositely; it acts to open the motor switch and stop the compressor with excessive rise of high side pressure, and to again close the switch and re-start the compressor when the high-side pressure falls to normal.

In some systems having a water-cooled condenser there is a *water failure switch* that opens the motor control circuit and stops the compressor should the pressure of the cooling water fall below that which maintains the necessary rate of water circulation, and which closes the switch to re-start the compressor when the water pressure again rises to normal. Water failure switches are somewhat like the low-side pressure controls in that they close with a rise of pressure and open with a drop of pressure. Of course, the bellows or diaphragm of the water failure switch is expanded and contracted

by pressure from the water piping rather than from any refrigerant pressure.

In addition to the high-pressure cutout switch some refrigeration installations have a *relief valve* connected between the discharge line from compressor to condenser and the suction line. This valve is normally held closed by a spring whose compression is adjustable to allow opening of the valve when high side pressure exceeds a safe operating limit. With the relief valve opened, high-pressure vapor from the discharge line goes over into the low-pressure side or the suction side of the compressor, thus providing positive relief on the high side without losing any refrigerant from the system. The high-pressure cutout is adjusted to act before pressure rises to a value that forces the relief valve to open, but should the cutout fail to act, the relief valve will prevent damage to the mechanism.

CHAPTER 6

MULTI-TEMPERATURE SYSTEMS

In many commercial refrigeration installations two or more spaces, or two or more liquid baths, must be maintained at different temperatures. For instance, only moderately low temperatures are required for refrigeration of butter, eggs, fruits and vegetables, while much lower temperatures are needed for meat storage and for making ice. Each of the desired temperatures is obtained from an evaporator suited to the particular temperature and load, with all the evaporators connected to a single compressor or to a single condensing unit.

Assuming that an evaporator is capable of handling its refrigeration load, the temperature of the refrigerated substances will depend on the evaporating pressure and temperature maintained within the evaporator, on the portion of the evaporator which contains evaporating refrigerant rather than superheated vapor, and on the temperature difference between refrigerated substances and the evaporator or on the temperature difference needed to maintain the necessary rate of heat transfer. In many cases there will be a difference of about 25° between evaporating temperature of the refrigerant and the temperature in refrigerated compartments or cabinets.

In examining multi-temperature installations we shall be concerned with various methods of controlling flow of refrigerant to and from the evaporator. These we may refer to as *refrigerant controls.* We shall be concerned also with various methods of starting and stopping the compressor in accordance with temperature or pressure. These we may refer

to as *cycling controls*, because they govern the periods or cycles of compressor operation and of compressor idleness between operating times. The cycling controls may be of either the pressure type, operating from low-side pressure applied to the motor control switch, or else of the temperature

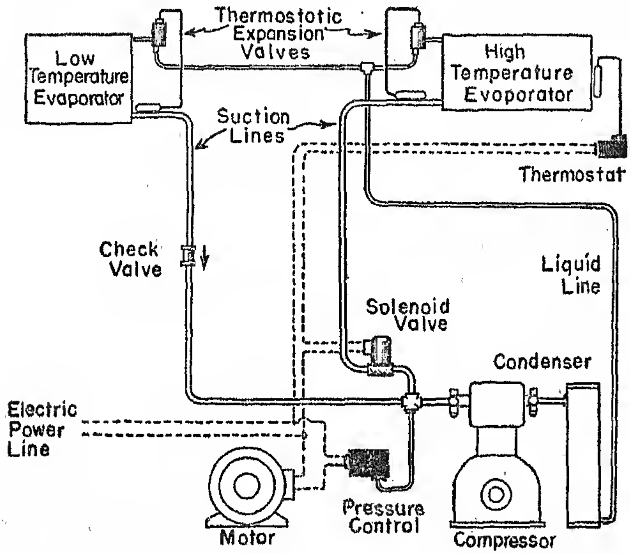

Fig. 69.—A Two-temperature System Employing a Solenoid Valve, Thermostat, and Check Valve.

type operating from a thermostatic bulb with a bellows or diaphragm to actuate the switch, or from some other style of temperature switch or thermostat switch. The refrigerant controls include thermostatic expansion valves, several types of multi-temperature valves designed especially for this service, and in some cases low-side float valves or even automatic expansion valves.

A Two-temperature System.—Fig. 69 illustrates

one method of obtaining two different refrigerating temperatures with two separate evaporators. The refrigerant control is a thermostatic expansion valve for each evaporator. The cycling control for the compressor is a low-side pressure type. The refrigeration controls and the cycling control introduce nothing new; they are types with which we already are familiar.

The additional control units for two-temperature operation in Fig. 69 include a *solenoid valve* in the suction line from the high temperature evaporator, a *thermostat* or temperature-operated electric switch

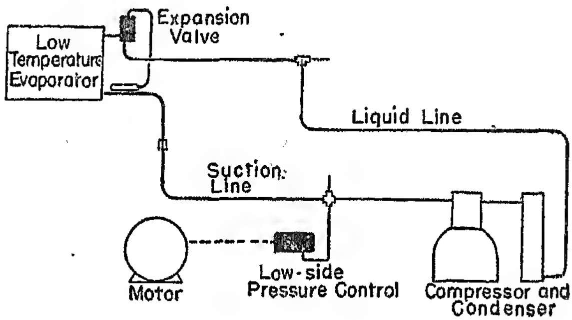

Fig. 70.—The Low-temperature Portion of the Two-temperature System.

for opening and closing the solenoid valve, and a *check valve* in the suction line from the low temperature evaporator.

The check valve is merely a small spring-loaded valve which permits free flow of vapor from evaporator to compressor through the suction line, but which automatically closes should there be a tendency for vapor to flow toward the evaporator. Were we to remove from Fig. 69 the high-temperature evaporator with its expansion valve, solenoid valve and thermostat, there would remain only the

parts indicated in Fig. 70. Here we have a familiar type of refrigeration system consisting of a thermostatic expansion valve as the refrigerant control and a low-side pressure control as the cycling control. The temperature range at which this low-temperature portion of the system operates will be determined by adjustment of the low-side pressure control, and the compressor will maintain a low-side pressure determined by adjustment of this pressure control.

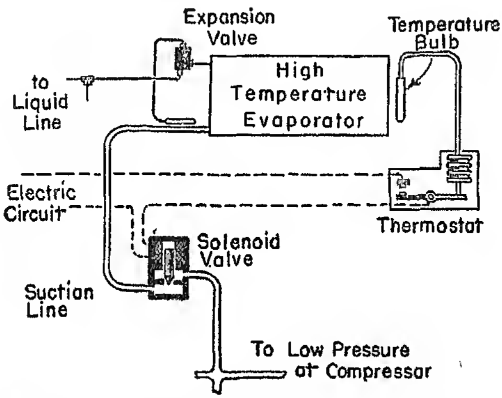

Fig. 71.—The High-temperature Portion of the Two-temperature System.

In Fig. 71 we have only the high-temperature portion of our two-temperature system, with the suction line for the evaporator connected through the solenoid valve to the low pressure maintained by the compressor. The needle of the solenoid valve is enclosed by and moved by a plunger which falls by its own weight to close the valve. When electricity flows in a coil surrounding the upper end of the plunger, the magnetism produced in the coil lifts the plunger to open the valve. Flow of electricity

for the solenoid valve comes through the switch contacts of the thermostat when these contacts are together, and there can be no flow while the contacts are apart. The thermostat switch is actuated by a bellows connected to a temperature bulb placed near the high-temperature evaporator or in any place where the refrigerating temperature is to be controlled.

When temperature rises, and the temperature bulb warms up, the thermostat bellows is expanded and the switch contacts are closed. This allows an electric flow which opens the solenoid valve. The suction side of the evaporator now is connected to the low pressure being maintained by the compressor, and refrigeration takes place at the evaporator. When the temperature falls by an amount corresponding to adjustment of the thermostat, the thermostat bellows contracts, the thermostat switch opens, the solenoid valve drops closed, and the evaporator is cut off from the compressor so that refrigeration ceases.

The low pressure maintained by the compressor is sufficiently low to satisfy the low-temperature evaporator, so always is lower than needed to satisfy the high-temperature evaporator. By means of the solenoid valve and thermostat, the high-temperature evaporator is connected to the low suction pressure at intervals and during periods which are determined by adjustment of the thermostat. Thus the temperature maintained by the high-temperature evaporator is regulated by adjustment of the thermostat, while temperature maintained by the low temperature evaporator is regulated by adjustment of the low-side pressure control. Temperature maintained by the high-temperature evaporator depends on how often and for how long the solenoid valve is opened to place the evaporator in

operation. So far as the high-temperature evaporator is concerned, opening of the solenoid valve is equivalent to starting the compressor, while closing of this valve is equivalent to stopping the compressor.

Solenoid Valves and Thermostats.—Fig. 72 shows the parts of a typical solenoid valve. The coil is a winding of many turns of insulated copper wire. It becomes a magnet and acts in every way like a magnet when electric current flows in the wire.

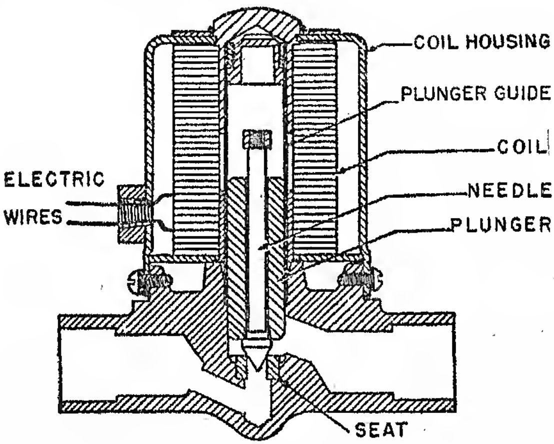

Fig. 72.—A Section Through a Solenoid Valve.

The plunger ordinarily is separate from the valve needle, so that the plunger rises a short ways and then strikes a collar on the needle to insure positive opening should there be any tendency for the needle to stick on the seat. In some solenoid valves there is a coiled spring that helps to hold the needle against the seat. Some valves have two needles, one within the other, and each with its own opening or seat. After the inner, smaller needle is raised, flow

of refrigerant helps raise the larger needle to give full opening of the valve.

Thermostat switches for operating solenoid valves may be of the temperature-operated type with a bellows and bulb or may be of the pressure-operated type with no bulb but with a connection for low-side pressure or any other pressure to the bellows. Both types are shown by Fig. 73. The temperature-operated switch may have the bulb attached to the evaporator, hung freely in an air space which is

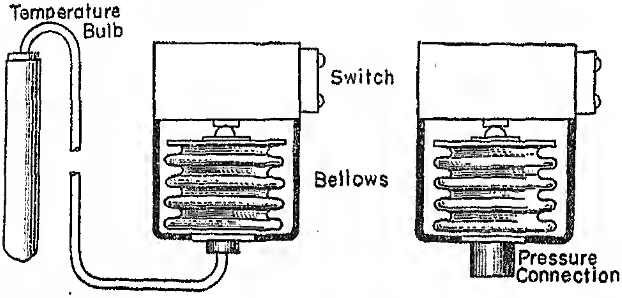

Fig. 73.—Thermostats May Operate from a Bulb or Directly from Low-side Pressure.

being refrigerated, or immersed in a liquid which is being refrigerated.

Check Valves.—The reason for using a check valve in the suction line from the low temperature evaporator is as follows: If refrigeration is not being required at either evaporator of Fig. 69 the compressor will be stopped by action of the pressure control. If the high-temperature evaporator then should require refrigeration, the solenoid valve would open and relatively high pressure vapor from the high-temperature evaporator would go through the opened solenoid valve into the low-temperature evaporator. There the vapor would condense to

liquid, because of the lower temperature, and this liquid would be drawn into the compressor when the compressor started. A check valve in the suction line for the low-temperature evaporator prevents this action. The construction of a typical check valve is shown by Fig. 74.

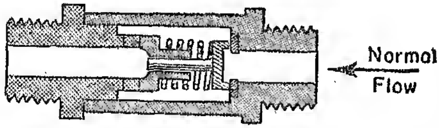

Fig. 74.—The Construction of a Check Valve.

If the compressor is idle, and the high-temperature evaporator requires refrigeration before the low-temperature unit, opening of the solenoid valve permits the high pressure from the relatively warm high-temperature evaporator to reach the low-side

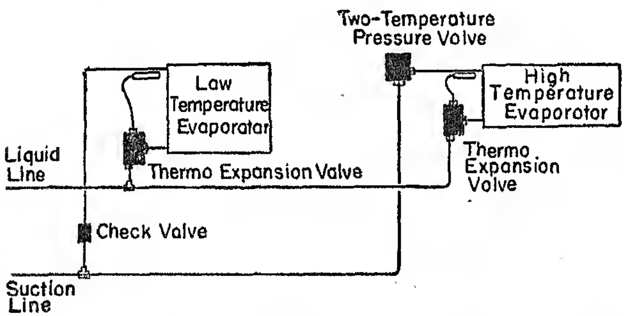

Fig. 75.—A Two-temperature System Employing a Two-temperature Pressure Valve and a Check Valve.

pressure control and this control then acts to start the compressor. Thus the compressor may be started by demands of the high-temperature evaporator just as well as by demands of the low-temperature evaporator.

Two-temperature Pressure Valve.—Instead of

using a solenoid valve in the suction line from the high-temperature evaporator we may, as in Fig. 75, use a two-temperature pressure valve which maintains in the high temperature evaporator a pressure which is higher than that at the low side of the compressor, and consequently maintains an evaporator temperature which is higher than that corresponding to the low-side pressure of the system. These valves are variously called suction pressure regulating valves, automatic regulating valves, constant pressure valves, and by other more or less descriptive names.

The construction of one style of two-temperature pressure valve is shown by Fig. 76. The valve needle is attached to and operated by a bellows. Below the bellows is a spring that tends to shorten the bellows. Inside the bellows, and, in effect, above the bellows, is an adjusting spring that tends to lengthen the bellows and close the valve. The underside of the bellows is reached by pressure at the suction line end of the evaporator, and the upper side is reached by pressure of the surrounding air or by atmospheric pressure. Thus a higher pressure and accompanying higher temperature in the evaporator tend to open the valve, while a lower evaporator pressure and temperature tend to let the valve close. The evaporator pressure at which the valve opens, or closes, is determined by the balance between spring pressures, evaporator pressures and atmospheric air pressures. Since the only one of these pressures that is adjustable is that of the adjusting spring, the evaporator pressure is regulated by changing the compression on this adjusting spring.

The two-temperature pressure valve is adjusted so that it closes, and shuts off its evaporator, at an evaporator pressure corresponding to the lowest

temperature that it is desired to maintain at this evaporator. When temperature and pressure at the evaporator rise above this minimum value the valve will open. The higher the temperature and

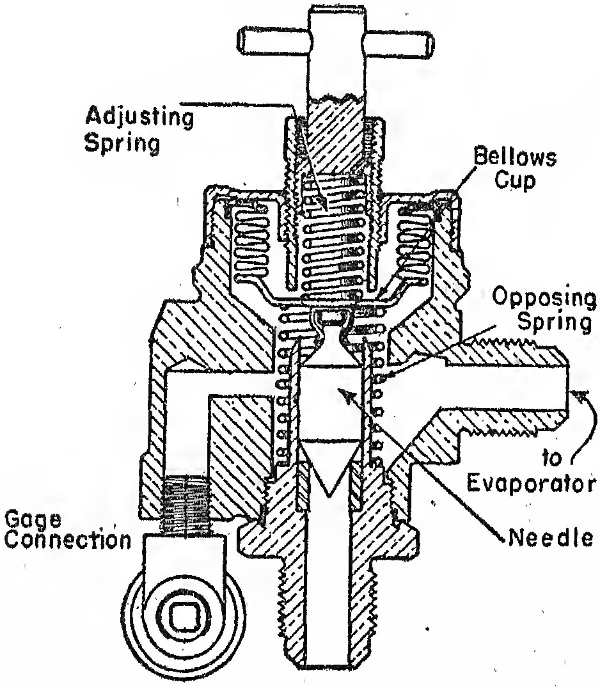

Fig. 76.—Construction of a Two-temperature Pressure Valve (Fedders).

pressure above the minimum the greater will be the opening of the valve. The valve normally "floats" partly open and allows vapor to be drawn out of the evaporator to maintain evaporation and refrigeration. If the temperature around the evaporator rises high enough, the valve will be opened

fully, and thereafter the pressure inside the evaporator will rise to a value which depends on the refrigerating load.

Like other multi-temperature controls, this two-temperature pressure valve can maintain its evaporator only at a pressure and temperature equal to or higher than that corresponding to the low-side pressure in the whole system. The higher operating pressure and temperature are determined by adjustment of the valve. They do not depend on the value

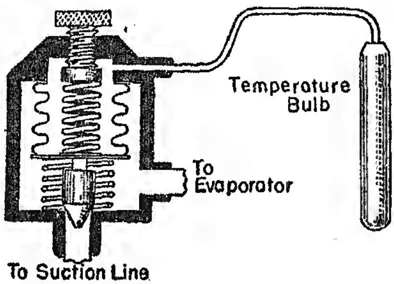

Fig. 77.—The Principle of a Two-temperature Thermal Valve.

of low-side pressure being maintained by the compressor.

Instead of using a two-temperature pressure valve which is actuated by and which controls pressure in the evaporator we may use a two-temperature thermal valve such as shown in principle by Fig. 77. This valve is similar to the pressure type except that the upper side of the bellows or the inside of the bellows is connected to a thermostatic bulb instead of being exposed to pressure of atmospheric air.

As do all devices employing thermostatic bulbs, the two-temperature thermal valve acts to maintain a constant temperature at the position of the bulb. The bulb is mounted either on the high-temperature

evaporator, in the refrigerated air space for this evaporator, or is immersed in a liquid whose temperature is regulated by the high-temperature evaporator. The valve normally floats in a partially open position in accordance with the rate of refrigeration required to maintain a constant temperature at the temperature bulb.

Snap-action Valve.—A snap-action valve is a two-temperature valve which acts similarly to a solenoid valve in either fully opening or fully closing the suction line, rather than floating in a partially open position, but the snap-action valve is actuated by pressure differences rather than electrically as is the solenoid valve.

Snap-action valves are actuated by a bellows exposed on one side to pressure in the evaporator and suction line, and on the other side to atmospheric air pressure. There is some sort of toggle mechanism which causes the valve needle to snap from fully closed to fully opened when evaporator pressure exceeds a value for which the valve is adjusted, and to snap back to the fully closed position when evaporator pressure, and temperature, have been lowered to the adjusted values.

Many snap action valves have two springs or two sets of springs, one controlling the pressure range and the other controlling the differential between pressures for opening and closing. Because of the rather delicate balance between the low evaporating pressures and the spring pressures the snap-action valve sometimes is adjusted with difficulty. As a consequence the solenoid valve is used more frequently than the snap-action type.

Multi-temperature System.—Fig. 78 shows two evaporators connected to a common liquid line and a common suction line. Many additional evaporators might be similarly connected to the same liquid and

suction lines, all being served by one compressor or one condensing unit, yet all having independent adjustments for temperature and load conditions.

The refrigerant control for each evaporator is a thermostatic expansion valve which may be adjusted for the desired degree of superheat in each evaporator. The thermostatic expansion valves are connected to the common liquid line through solenoid valves whose opening and closing is controlled by temperature-actuated thermostats at or near

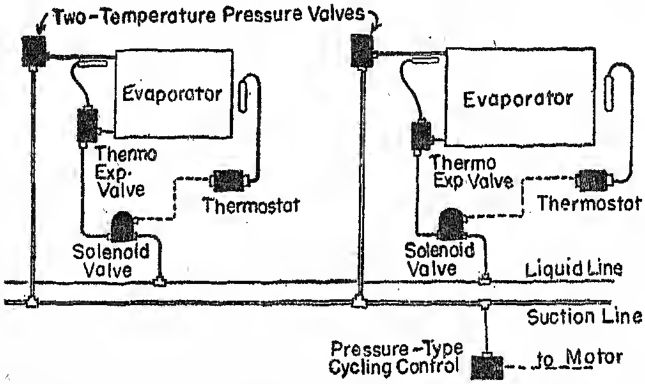

Fig. 78.—Two Evaporators in a Multi-temperature System to Which Might Be Connected Additional Evaporators.

each evaporator. These thermostats may be adjusted for whatever temperature is required at each evaporator.

Between each evaporator and the common suction line is a two-temperature pressure valve which may be adjusted to close the suction connection at some minimum pressure in the evaporator, and otherwise to provide a varying or floating suction opening which will reduce the low pressure in the main suction line to one suited to the particular evaporator.

Note that the floating type two-temperature pressure valve is in the suction line, while the positive acting solenoid valve is in the liquid line for each evaporator. The thermostat opens and closes the solenoid valve in accordance with temperature changes at the evaporator, just as any temperature control for cycling might start and stop a compressor connected to only the one evaporator.

The compressor or condensing unit is started and stopped by a pressure type of cycling control. This control is adjusted to maintain a suction line pressure somewhat below the lowest evaporating pressure required in any one of the connected evaporators, consequently the compressor will run so long as there is need to produce evaporating pressure in any one or more evaporators. If none of the evaporators require refrigeration all solenoid valves will be closed, and pressure in the suction system will be reduced to a point at which the compressor is stopped.

Cycling Controls.—In the multi-temperature systems which have been examined, the cycling control for the compressor always has been a low-side pressure type. With such a control connected to the low side or to the suction connections for all the evaporators, and adjusted to maintain a pressure low enough for the coldest evaporator, there always will be a pressure sufficiently low for all evaporators. So long as any evaporator in the system requires refrigeration, the temperature and pressure for that evaporator will be above the minimum setting of the pressure cycling control and the compressor will be operated.

Were a temperature-type of cycling control used for a multi-temperature system, and were only one such control employed, it would have to be located

at one or the other of the evaporators and would operate only in accordance with temperature at that evaporator. Ordinarily the one temperature-type cycling control unit would be located at the coldest evaporator so that the compressor would not cut out until the suction needs of that low-temperature evaporator were satisfied. Such an arrangement is shown by Fig. 79. In the suction line of the high-temperature evaporator is some type of two-temperature valve, a solenoid or a suction pressure valve,

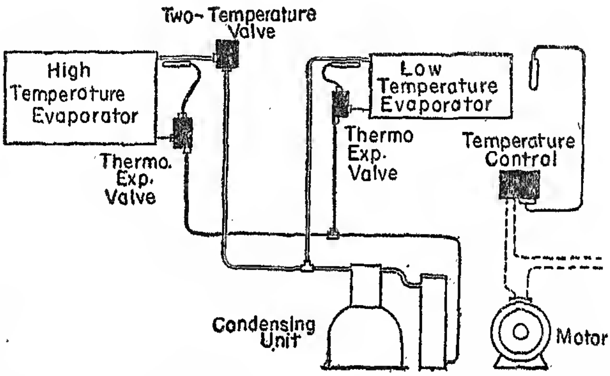

Fig. 79.—A Two-temperature System with Which the Compressor Is Controlled by the Lower Temperature.

which shuts off this high-temperature evaporator when its temperature and pressure reach the lowest levels at which this part of the apparatus is to operate.

A difficulty with the system of Fig. 79 is that, should refrigeration be required at the high-temperature evaporator and not at the low-temperature unit, the compressor will not be started—since the cycling control operates only from temperature at the low-temperature evaporator.

Individual Temperature-type Cycling Controls.—

Fig. 80 shows a method of using individual temperature controls for each evaporator, with temperature control for cycling arranged in such manner that the compressor will be started when any one or more evaporators require refrigeration, and regardless of the condition at other evaporators.

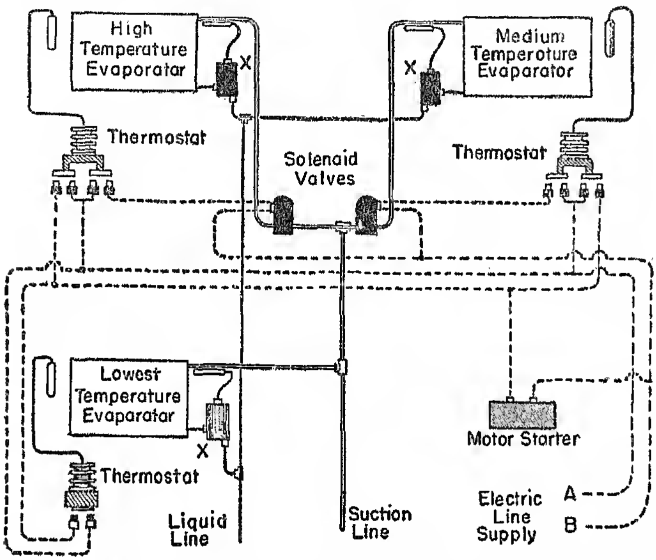

Fig. 80.—A Multi-temperature System with Which Temperature at Any Evaporator Will Start the Compressor.

The refrigerant control for each evaporator is a thermostatic expansion valve *X*, with all these valves connected to the common liquid line. The thermostats for the medium-temperature and high-temperature evaporators are of the two-pole type, meaning that they open or close two separate electric circuits at the same time. These thermostats are of the bellows type, with temperature bulbs. The lowest-temperature evaporator has a single-pole

thermostat which handles only one electric circuit.

In the suction lines of the medium-temperature and high-temperature evaporators are solenoid valves operated by the respective thermostats and connected to the common suction line. The lowest-temperature evaporator is connected directly to this common suction line. Any number of additional evaporators might be used, each equipped with an expansion valve, a two-pole thermostat and a solenoid valve, and each connected just as are the medium-temperature and low-temperature evaporators of Fig. 80.

When any two-pole thermostat closes its switch contacts because of rise of temperature at its evaporator, one set of thermostat contacts completes a circuit through the solenoid valve to connect this evaporator to the suction line. The other set of thermostat contacts complete the "pilot circuit" through the starter for the compressor motor and the compressor starts if it is not already running. The thermostat for the lowest temperature evaporator is connected only in the motor starter circuit, since this unit requires no solenoid valve. The solenoid valves on the higher temperature evaporators prevent warm, high-pressure vapor from those evaporators getting into the lowest-temperature evaporator and condensing there while the compressor is idle.

The electric circuit from the line supply may be traced from *A* to the common connection of the two-pole thermostats and to the single-pole thermostat, then through any one pair of contacts, through the motor starter, and back to *B*. Going through the second set of contacts on the two-pole thermostats, the circuit passes through the solenoid valves and back to *B*. Since the motor starting contacts of the two-pole thermostats are wired in parallel, the

motor will be started when any one or more of these thermostats act, and it will continue to drive the compressor until all the thermostat contacts are opened, which means that none of the evaporators then require refrigeration.

Using Automatic Expansion Valves.—In all of the multi-temperature systems which have been shown the several evaporators are fed directly from a single liquid line, and all are connected directly to a single suction line. The supply of liquid refrigerant divides between the evaporators, part of it going to each. In any system where the refrigerant divides between the evaporators, and where the portion of the refrigerant passing through one evaporator passes through no other, the evaporators are in *multiple* or are *multiplexed*. On all of these multiplexed evaporators we have used thermostatic expansion valves as refrigerant controls. Such valves may be used to feed either dry evaporators or flooded evaporators. Low side float valves might be used instead of thermostatic expansion valves for flooded evaporators.

Different temperatures cannot be obtained in multiplexed evaporators fed from a single automatic expansion valve, as in Fig. 81, because the automatic expansion valve is a constant-pressure control and would maintain the same evaporating pressure and temperature in both evaporators.

Several evaporators may be connected together in series and fed from a single automatic expansion valve as in Fig. 82. The evaporating pressure, and temperature, will be approximately the same in all the series evaporators. But because there must be some difference between pressures in various parts of a refrigerant circuit in order that liquid and vapor may flow through the circuit, the pressures in series evaporators near the suction line will be

somewhat lower than in those near the expansion valve, and if there is evaporating refrigerant in the lower-pressure evaporators their temperature will be somewhat lower. However, if unevaporated refrigerant does not go all the way through to the suction line there will be superheating and higher temperatures in evaporators near the suction line.

With series evaporators, where the same refrigerant passing through one passes also through all the others, the coil size and area of heat absorbing

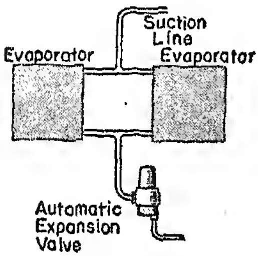

Fig. 81.—An Automatic Expansion Valve Maintains the Same Pressure and Temperature in All Connected Evaporators.

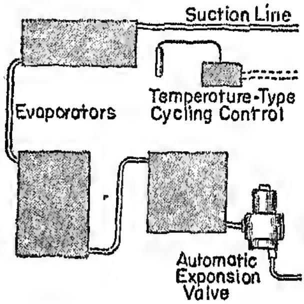

Fig. 82.—Several Evaporators May Be Connected in Series to a Single Automatic Expansion Valve.

surface must be carefully calculated for each evaporator in accordance with the refrigerating load at the evaporator. A change of load at any one evaporator may affect the performance of other evaporators in the series system.

Since an automatic expansion valve is a constant-pressure type we cannot use a low-side pressure control for cycling, but must use some form of temperature-actuated cycling control. With a single temperature-actuated cycling control, which is located at only one of several evaporators, the com-

pressor operation will depend on the temperature at only this one evaporator. To operate the compressor in accordance with refrigeration demands at any evaporator it would be necessary to employ some such scheme as illustrated in Fig. 80.

Single-temperature Multi-evaporator Systems.—There are many refrigeration installations in which several evaporators may be operated at the same or nearly the same temperature. Fig. 83 illustrates two evaporators in two separate cabinets or com-

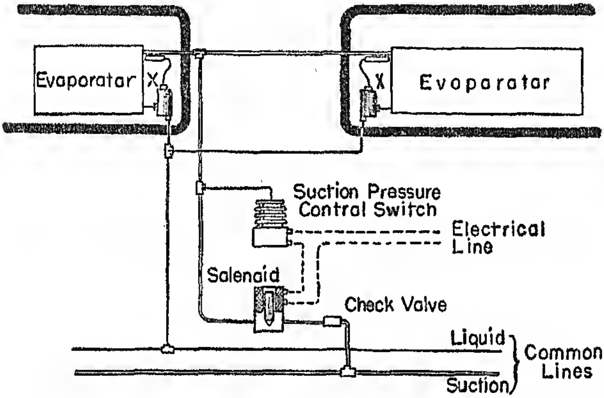

Fig. 83.—Two Evaporators Operating at the Same Temperature but with Different Loads.

partments. Temperature control is by means of a single solenoid valve in the suction line coming from both evaporators. The solenoid is actuated by a switch that is opened and closed by rise and fall of suction pressure in the two evaporators, and since both evaporators thus are controlled for the same suction pressure or evaporating pressure they will operate at the same temperature. To enable the two evaporators to carry different loads, and to keep fully refrigerated at the same time, each is equipped with a thermostatic expansion valve *X*.

The two single-temperature evaporators of Fig. 83 are shown connected to common suction and liquid lines. These common lines may serve other evaporators operating at various temperatures and equipped with any suitable types of refrigerant controls and cycling controls such as have been shown in previous "hookups."

Fig. 84 shows two evaporators in the same cabinet or compartment. Each evaporator is fitted with a

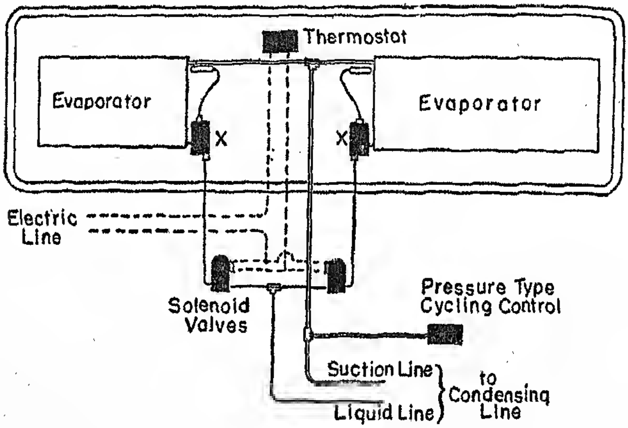

Fig. 84.—Two Evaporators Operating at the Same Temperature in One Cabinet.

thermostatic expansion valve to maintain desirable amounts of superheat with varying loads. In the liquid line connection from each evaporator is a solenoid valve. Both solenoids are operated simultaneously from a single thermostat or temperature control switch located in the cabinet. As cabinet temperature rises, the thermostat switch closes to place both evaporators in operation, and as cabinet temperature falls the thermostat switch opens to cut off both evaporators by means of their solenoid

valves. The condensing unit for this system would be operated by a pressure-type cycling control connected to the low side of the installation.

Fig. 85 shows several evaporators which might be of the flooded type with low-side floats or with thermostatic expansion valves for refrigerant control. All the evaporators are supplied from a common liquid line, and all connect to a common suction

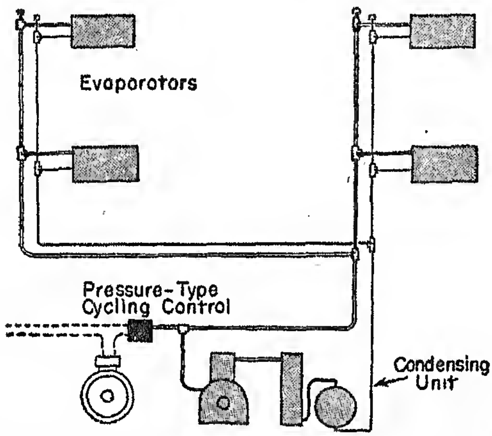

Fig. 85.—A Single-temperature System Handling Many Evaporators.

line. The cycling control is of the pressure type located near the condensing unit and connected to the low-side tubing or piping of the system. Evaporating pressure in all the evaporators will be maintained at a value determined by adjustment of the cycling control, so all will operate at the same or approximately the same temperature. The low-side floats or the thermostatic expansion valves at each of the evaporators will enable each to carry its individual refrigeration load without being affected

by the conditions at any other evaporator in the system.

When evaporators in a single-temperature system are fitted with thermostatic expansion valves it is possible to operate them at slightly different temperatures by adjusting the expansion valves. Reducing the rate of refrigerant flow through the expansion valve will increase the superheat and will restrict the cooling effect to a smaller portion of the evaporator. Thus the cabinet space will reach a higher temperature than produced with the entire

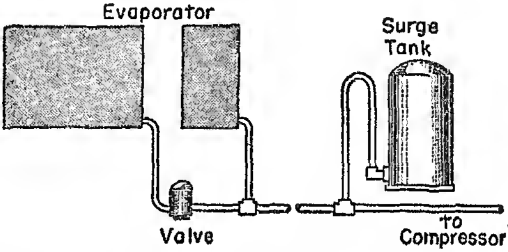

Fig. 86.—A Surge Tank to Reduce Changes of Pressure in a System.

evaporator active and with a lower superheat. Where only a few degrees of temperature variation is desired this method is satisfactory. However, it is uneconomical because the evaporators working at higher temperatures are operating at low efficiency.

Surge Tank.—When two or more evaporators are connected to a common suction line, and when some of the evaporators may be periodically connected to and disconnected from the suction line, the total capacity or volume of the low side may be materially changed by the cutting in or out of one relatively large evaporator. If a large high-temperature, high-pressure evaporator is suddenly connected to

a low side on which, for example, only one smaller evaporator is operating, the pressure would rise in the entire low side, including the smaller evaporator. The pressure would remain too high for the requirements of the smaller evaporator until the compressor could pump out enough vapor to get the pressure down again. Such a condition might exist in the two evaporators of Fig. 86. The greater the number of evaporators connected to the same low side the less will be the effect on pressure when any one is cut in or out.

To reduce the changes of pressure a surge tank sometimes is connected to the common suction line, as shown in Fig. 86. The surge tank is simply a heat-insulated chamber of possibly two or three cubic foot capacity. Pressure in this tank is reduced by action of the compressor. Then, when an extra evaporator cuts in, the higher pressure of that evaporator is largely compensated for by the surge tank with its considerable volume of low-pressure vapor.

CHAPTER 7

TEMPERATURE AND PRESSURE MEASUREMENTS

The great majority of service and repair operations on refrigeration apparatus require measurements of temperatures, pressures, or both. It is common practice in the United States to measure all refrigeration temperatures in degrees of the Fahrenheit thermometer scale, on which 32° represents the temperature of melting ice, and 212° the temperature of water which is boiling at sea-level atmospheric pressure or at a pressure of 14.7 pounds per square inch. The Fahrenheit temperature scale between 32° and 212° is divided into 180 equal degrees, and similar degree divisions are extended below and above these points.

On the centigrade temperature scale the temperature of melting ice is at 0° and that of boiling water is at 100°, with the space between divided into 100 equal degrees. To change a centigrade temperature to the equivalent Fahrenheit temperature proceed as follows:

1. Multiply the number of centigrade degrees by 9, then divide the result by 5. If the original centigrade temperature is below zero, or is a minus number, the number resulting from this first step will be a minus number.

2. With the number determined in step *1* above combine +32, which is a positive number. The sum is the equivalent Fahrenheit temperature.

Example: To change —10° centigrade to the equivalent Fahrenheit degrees.

$-10 \times 9 = -90$

$-90 \div 5 = -18$

-18 combined with $+32 = +14°$ Fahrenheit.

Pressure Measurements.—All gases, including air, exert pressure against everything with which they are in contact. This pressure exists because the exceedingly small molecules composing gases are in continual rapid movement, and because they strike against objects to produce the forces or pressures of impacts just as pressure would be exerted on objects being pelted with baseballs or with drops of rain. The amount of pressure exerted by a gas depends on the temperature of the gas, because it is temperature that determines the velocity or speed with which the molecules travel. Pressure depends also on the concentration or density of gas molecules in a given space or volume, the greater the density the higher the pressure because then there are more molecules striking any given surface area.

There are forces of attraction between all bodies. The attractive force exerted by the earth is called gravity. The attraction between the earth and the molecules of gases in air causes a density of air at sea level which is great enough to produce a pressure of 14.7 pounds per square inch. Since this pressure results from impacts of gas molecules it acts equally in all directions; upward and sideways as well as downward.

Fig. 87 shows a pressure-measuring instrument, or gage, consisting of a flexible diaphragm between two chambers. At *A* both chambers are open to atmospheric air, there are equal pressures of 14.7 pounds per square inch on opposite sides of the diaphragm and the diaphragm is balanced. The point at which the pointer stands on its scale is marked zero, meaning that there is no difference between the pressures on opposite sides of the diaphragm.

If one of the chambers of the gage is connected to a pressure greater than atmospheric pressure, and the other remains open to the atmosphere, the diaphragm will be distended as shown in full lines by diaphragm *B*. If the measured pressure is 5 pounds greater than atmospheric pressure the pointer will move to a point marked "+5" on the scale.

Should the measured pressure be less than pressure in the surrounding air the diaphragm would be distended as shown by broken lines in diagram

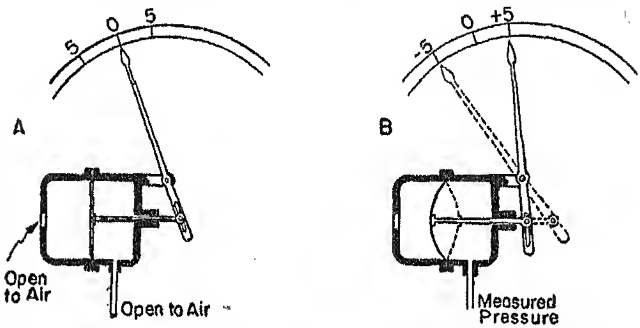

Fig. 87.—The Basic Operating Principle of a Pressure Gage.

B of Fig. 87, this because atmospheric air pressure then is greater than the measured pressure. The pointer will move as shown by broken lines, to a point which indicates how much less is the measured pressure than that of surrounding air. Pressures measured with reference to atmospheric air pressure are called *gage pressures*. These are the pressures measured and indicated by all ordinary pressure gages.

Considered with reference to a total absence of all pressure, or with reference to an absolute zero in pressure, our zero *gage pressure* really is a

pressure of 14.7 pounds per square inch. Pressures considered with reference to no pressure at all as the zero value are called *absolute pressures*. An absolute pressure always is 14.7 pounds per square inch greater than the equivalent gage pressure. Any absolute pressure is changed to the equivalent gage pressure by subtracting 14.7 pounds, and any gage pressure is changed to the equivalent absolute pressure by adding 14.7 pounds per square inch.

Vacuums.—In refrigeration work all pressures

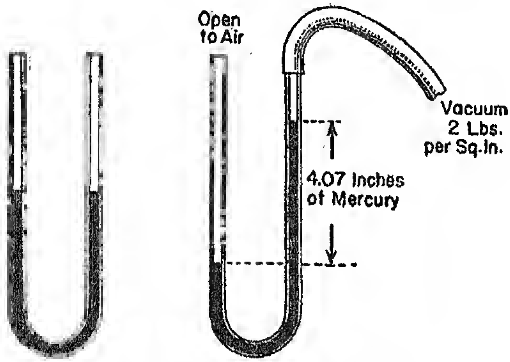

Fig. 88.—A U-tube Measures Pressure Differences by Differences in Height of Mercury Columns.

below zero gage pressure are called vacuums, or all pressures below 14.7 pounds per square inch absolute pressure are called vacuums.

It would be entirely possible to measure vacuums as so many pounds per square inch below zero gage pressure, and to call them minus or negative pressures. However, vacuums are measured in *inches of mercury* rather than in pounds per square inch. If a U-shaped tube with open ends is partially filled with mercury, as at the left in Fig. 88, the levels of mercury will be the same in both legs of the tube—

this because both surfaces of mercury are subjected to the same atmospheric pressure. If one leg of the tube now is connected to a vacuum of 2 pounds per square inch, and the other leg left open to the air, the mercury will rise in the vacuum side to a level 4.07 inches higher than in the side open to the air.

A vacuum of 2 pounds per square inch is equal to a vacuum of 4.07 *inches of mercury*, so each pound per square inch is equal to 2.035 inches of mercury. We generally figure 2 inches of mercury as equal to 1 pound per square inch, or 1 inch of mercury as

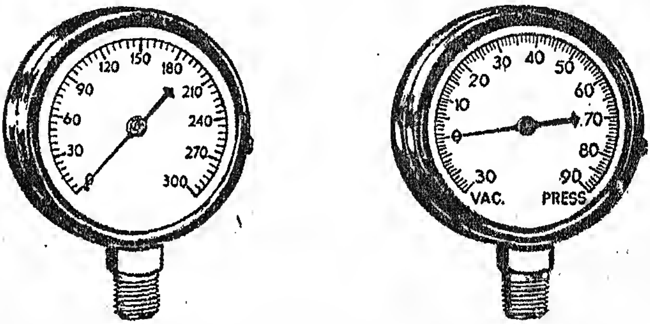

Fig. 89.—A Pressure Gage and a Compound Gage.

equal to ½ pound per square inch; this relation being close enough for all usual purposes.

Pressure Gages and Vacuum Gages.—The two types of gages illustrated by Fig. 89 are generally used for refrigeration service work. At the left is an instrument reading gage pressures from zero to 300 pounds per square inch. This is called a *pressure gage* and is used for measuring pressures in the high side of the refrigeration system. The other gage measures from a vacuum of 30 inches of mercury up to zero, then measures pressures from zero to 90 pounds per square inch. This instrument is called a *compound gage*, and is used for measuring

vacuums and pressures in the low side of the refrigeration system. Other ranges of vacuums and pressures are available.

The mechanism of refrigeration gages seldom includes diaphragms or bellows for the pressure-sensitive element, but ordinarily includes a hollow, slightly flattened metallic tube formed into part of a circle. This is a *Bourdon tube*. One end is sealed closed, and the other is connected to the part of the system in which pressures are to be measured. Increase of pressure tends to straighten the tube, while decrease of pressure tends to bring it to a smaller circle. A toothed pinion and sector (part of a gear wheel) transfer motion from the tube to the pointer.

Whether a gage or a control unit has a diaphragm, a bellows, or a Bourdon tube for the pressure-sensitive element makes no difference in the basic principle of response to pressure changes. Any element is expanded or contracted, lengthened or shortened, by differences between pressures on opposite sides of the element or on the inside and outside of the element. Any increase of pressure on one side acts just like a corresponding decrease on the other side, and a decrease on the first side acts like an increase on the second side.

Effect of Altitude.—As we go from sea-level to higher altitudes the density of atmospheric air decreases, and consequently the pressure decreases to values less than the average of 14.7 pounds per square inch for sea level. The decrease in air pressure is very close to one-half pound per square inch per 1,000 feet of altitude, so is close to one inch of mercury in vacuum measurements for each rise of 1,000 feet above sea level.

If we assume that Fig. 90-A represents the operating principle of any type of pressure gage, which it actually does, it is quite plain that a decrease of

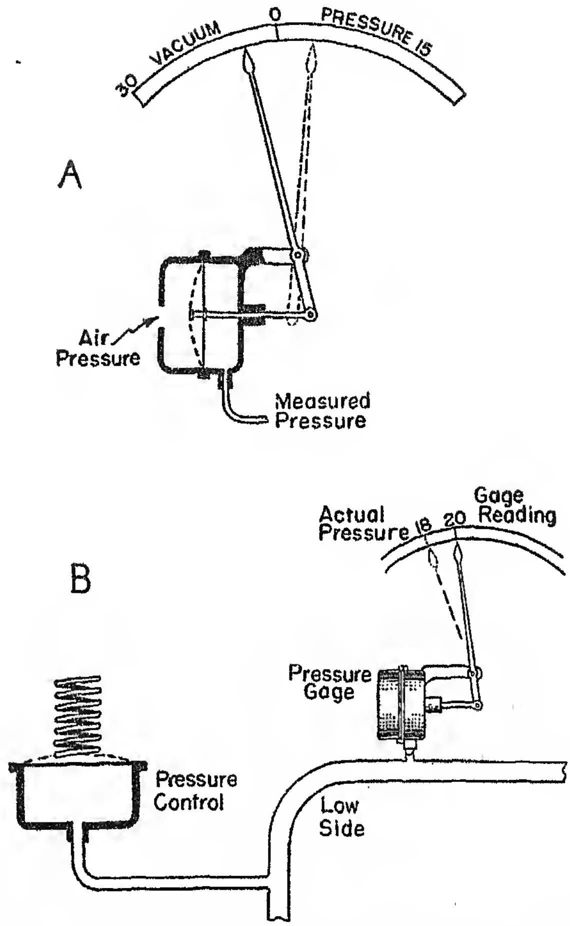

Fig. 90.—A Pressure Gage and the Manner in Which Its Reading May Be Affected by Altitude.

pressure in the surrounding air will cause the pointer to move to the right on its scale. Moving the pointer to the right causes it to indicate fewer inches of mercury at the vacuum end of the scale,

or to indicate more pounds per square inch at the pressure end of the scale. That is, the gage reading will show less than actual vacuum or more than actual pressure being measured. To correct the readings we should add to vacuum readings one inch per 1,000 feet of altitude above sea level, and should subtract from pressure readings one-half pound per square inch for every 1,000 feet of altitude. This will give vacuums and pressures actually existing in the refrigeration system.

Changes of air pressure with changes of altitude affect the operation of pressure-type cycling controls as well as affecting pressure gages. We may let Fig. 90-B represent a pressure-type cycling control of the diaphragm style connected to a low side. Assume, just for an example, that the control has been adjusted for cut-in at a low side pressure of 20 pounds at sea level, and that the apparatus is taken to an altitude of 2,000 feet. The lessened air pressure on the side of the diaphragm opposite that exposed to low side pressure allows the diaphragm to move upward as shown by the broken line. This upward movement of the diaphragm will close the electric contacts too soon, or with a low side pressure of less than 20 pounds. Allowing ½ pound per 1,000 feet, the 4,000-foot altitude makes a change of 2 inches, so cut-in will occur at 18 pounds low-side pressure and at a correspondingly low temperature. To bring the cut-in point back to 20 pounds pressure we will have to increase the tension on the range adjusting spring.

If the cycling control is adjusted at the higher altitude with a gage whose readings are corrected for that altitude, the adjustment is easily made for an actual cut-in pressure of 18 pounds. However, if the gage reads for sea-level air pressure, and its readings are not corrected for altitude, the gage

will read 2 pounds high, and if the control is adjusted to cut in at a gage reading of 20 pounds the cut-in actually will occur at 18 pounds low side pressure, as shown in Fig. 90-B.

Refrigerant Tables.—The accompanying tables give some of the "thermodynamic properties" of the three common refrigerants, Freon-12, sulphur dioxide, and methyl chloride. The tables apply to saturated vapors at temperatures from 40° below zero to 140° above zero, thus including all the usual ranges for both evaporation and condensation.

Pressures are given for both gage and absolute values, the difference always being 14.7 pounds per square inch. Values below zero gage are given in inches of mercury or in vacuums. In the third column of each table are listed the latent heats in Btu's per pound of vapor for either evaporation or condensation, depending on which of these is taking place at the listed temperature.

If, at any given temperature, refrigerant liquid is evaporating into vapor, the latent heat values give the number of Btu's absorbed by each pound of refrigerant while it evaporates, but if vapor is condensing into liquid, the values are Btu's lost by each pound of refrigerant while condensing.

The latent heats at condensing temperatures, say from 70° to 110°, are much less than those at evaporating temperatures, which may be from 0° to 40°. Therefore, a pound of refrigerant loses less heat when condensing than it absorbs when evaporating. In addition to the heat absorbed during evaporation, more heat must be added to bring the vapor up to the condensing temperature. Then part of all the heat is lost during condensation without change of temperature, and the remainder is lost when the hot condensed liquid is cooled to the evaporating temperature.

FREON-12 (Saturated Vapor)
Temperatures, Pressures and Latent Heats

Temp. °F.	Pressure Lbs. per Sq. In. Gage	Abs.	Latent Heat vapor Btu/lb
– 40	10.94*	9.32	73.50
– 35	8.33*	10.60	73.09
– 30	5.45*	12.02	72.67
– 25	2.28*	13.56	72.25
– 20	0.58	15.28	71.80
– 15	2.46	17.16	71.36
– 10	4.50	19.20	70.91
– 5	6.74	21.44	70.44
0	9.17	23.87	69.96
2	10.19	24.89	69.77
4	11.26	25.96	69.57
5	11.81	26.51	69.47
6	12.35	27.05	69.37
8	13.48	28.18	69.17
10	14.65	29.35	68.97
12	15.86	30.56	68.77
14	17.10	31.80	68.56
16	18.38	33.08	68.35
18	19.70	34.40	68.15
20	21.05	35.75	67.94
22	22.45	37.15	67.72
24	23.88	38.58	67.51
26	25.37	40.07	67.29
28	26.89	41.59	67.07
30	28.46	43.16	66.85
32	30.07	44.77	66.62
34	31.72	46.42	66.40
36	33.43	48.13	66.17
38	35.18	49.88	65.94
40	36.98	51.68	65.71
42	38.81	53.51	65.47
44	40.70	55.40	65.24
46	42.65	57.35	65.00
48	44.65	59.35	64.74
50	46.69	61.39	64.51
52	48.79	63.49	64.27
54	50.93	65.63	64.02
56	53.14	67.84	63.77
58	55.40	70.10	63.51
60	57.71	72.41	63.25
62	60.07	74.77	62.99
64	62.50	77.20	62.73
66	64.97	79.67	62.47
68	67.54	82.24	62.20
70	70.1	84.8	61.92
72	72.8	87.5	61.65
74	75.5	90.2	61.38
76	78.3	93.0	61.10
78	81.2	95.9	60.81
80	84.1	98.8	60.52
82	87.0	101.7	60.23
84	90.1	104.8	59.94
86	93.2	107.9	59.65
88	96.4	111.1	59.35
90	99.6	114.3	59.04
92	103.0	117.7	58.73
94	106.3	121.0	58.42
96	109.8	124.5	58.10
98	113.3	128.0	57.78
100	116.9	131.6	57.46
102	120.6	135.3	57.14
104	124.3	139.0	56.80
106	128.1	142.8	56.46
108	132.1	146.8	56.12

* Vacuums in inches of mercury.

FREON-12 (Saturated Vapor)

Temperatures, Pressures and Latent Heats

Temp. °F.	Pressure Lbs. per Sq. In. Gage	Abs.	Latent Heat vapor Btu/lb	Temp. °F.	Pressure Lbs. per Sq. In. Gage	Abs.	Latent Heat vapor Btu/lb
110	136.0	150.7	55.78	124	166.1	180.8	53.24
112	140.1	154.8	55.43	126	170.7	185.4	52.85
114	144.2	158.9	55.08	128	175.4	190.1	52.46
116	148.4	163.1	54.72	130	180.2	194.9	52.07
118	152.7	167.4	54.36	135	192.6	207.3	51.05
120	157.1	171.8	53.99	140	205.5	220.2	50.00
122	161.5	176.2	53.62				

SULPHUR DIOXIDE (Saturated Vapor)

Temperatures, Pressures and Latent Heats

Temp. °F.	Pressure Lbs. per Sq. In. Gage	Abs.	Latent Heat vapor Btu/lb	Temp. °F.	Pressure Lbs. per Sq. In. Gage	Abs.	Latent Heat vapor Btu/lb
– 40	23.54*	3.14	178.6	20	2.48	17.18	165.3
– 35	22.41*	3.69	177.8	22	3.33	18.03	164.7
– 30	21.10*	4.33	177.0	24	4.19	18.89	164.2
– 25	19.63*	5.06	176.1	26	5.10	19.80	163.6
				28	6.03	20.73	163.0
– 20	17.93*	5.88	175.1				
– 15	16.05*	6.81	174.1	30	7.00	21.70	162.4
– 10	13.91*	7.86	173.0	32	8.01	22.31	161.8
– 5	11.52*	9.04	171.8	34	9.05	23.75	161.2
0	8.85*	10.35	170.6	36	10.12	24.82	160.5
				38	11.25	25.95	159.9
2	7.70*	10.91	170.1				
4	6.51*	11.50	169.6	40	12.40	27.10	159.3
5	5.88*	11.81	169.4	42	13.59	28.29	158.6
6	5.25*	12.12	169.1	44	14.82	29.52	158.0
8	3.97*	12.75	168.6	46	16.09	30.79	157.3
				48	17.40	32.10	156.6
10	2.60*	13.42	168.1				
12	1.17*	14.12	167.5	50	18.75	33.45	156.0
14	0.14	14.84	167.0	52	20.16	34.86	155.3
16	0.89	15.59	166.4	54	21.61	36.31	154.6
18	1.67	16.37	165.9	56	23.10	37.80	153.9
				58	24.63	39.33	153.2

* Vacuums in inches of mercury.

SULPHUR DIOXIDE (Saturated Vapor)

Temperatures, Pressures and Latent Heats

Temp. °F.	Pressure Lbs. per Sq. In. Gage	Abs.	Latent Heat vapor Btu/lb	Temp. °F.	Pressure Lbs. per Sq. In. Gage	Abs.	Latent Heat vapor Btu/lb
60	26.23	40.93	152.5	100	69.8	84.5	137.2
62	27.88	42.58	151.8	102	72.8	87.5	136.4
64	29.57	44.27	151.1	104	75.8	90.5	135.7
66	31.30	46.00	150.3	106	78.9	93.6	134.7
68	33.08	47.78	149.6	108	82.1	96.8	133.9
70	34.92	49.62	148.9	110	85.2	99.9	133.1
72	36.84	51.54	148.1	112	88.9	103.6	132.2
74	38.78	53.48	147.4	114	92.2	106.9	131.4
76	40.78	55.48	146.6	116	95.7	110.4	130.5
78	42.86	57.56	145.9	118	99.1	113.8	129.6
80	44.98	59.68	145.1	120	102.8	117.5	128.8
82	47.18	61.88	144.4	122	106.2	120.9	127.9
84	49.44	64.14	143.6	124	110.0	124.7	127.0
86	51.75	66.45	142.8	126	114.0	128.7	126.1
88	54.14	68.84	142.0	128	118.0	132.7	125.2
90	56.55	71.25	141.2	130	121.9	136.6	124.4
92	59.00	73.70	140.4	135	132.4	147.1	122.1
94	61.60	76.30	139.6	140	143.9	158.6	119.9
96	64.33	79.03	138.8				
98	67.07	81.77	138.0				

METHYL CHLORIDE (Saturated Vapor)

Temperatures, Pressures and Latent Heats

Temp. °F.	Pressure Lbs. per Sq. In. Gage	Abs.	Latent Heat vapor Btu/lb	Temp. °F.	Pressure Lbs. per Sq. In. Gage	Abs.	Latent Heat vapor Btu/lb
− 40	15.91*	6.88	190.64	− 5	2.10	16.80	183.09
− 35	13.96*	7.84	189.23	0	4.10	18.80	181.98
− 30	11.52*	9.04	188.52				
− 25	8.92*	10.32	187.06	2	4.84	19.54	181.52
				4	5.80	20.50	181.05
− 20	6.06*	11.72	186.36	5	6.28	20.98	180.84
− 15	3.07*	13.19	185.28	6	6.70	21.40	180.58
− 10	0.20	14.90	184.21	8	7.61	22.31	180.10

* Vacuums in inches of mercury.

METHYL CHLORIDE (Saturated Vapor)

Temperatures, Pressures and Latent Heats

Temp. °F.	*Pressure Lbs. per Sq. In.*		*Latent Heat vapor Btu/lb*
	Gage	*Abs.*	
10	8.60	23.30	179.65
12	9.58	24.28	179.16
14	10.66	25.36	178.69
16	11.78	26.48	178.21
18	12.91	27.61	177.74
20	14.10	28.80	177.27
22	15.29	29.99	176.80
24	16.48	31.18	176.32
26	17.74	32.44	175.85
28	19.08	33.78	175.38
30	20.50	35.20	174.90
32	21.83	36.53	174.42
34	23.27	37.97	173.94
36	24.76	39.46	173.50
38	26.30	41.00	173.00
40	27.90	42.60	172.42
42	29.59	44.29	171.92
44	31.32	46.02	171.41
46	33.08	47.78	170.90
48	34.92	49.62	170.41
50	36.81	51.51	169.90
52	38.73	53.43	169.40
54	40.72	55.42	168.90
56	42.72	57.42	168.40
58	44.73	59.43	167.88
60	46.88	61.58	167.38
62	48.08	63.78	166.86
64	51.42	66.12	166.31
66	53.78	68.48	165.79
68	56.22	70.92	165.21
70	58.70	73.40	164.67
72	61.30	76.00	164.08
74	63.91	78.61	163.51
76	66.68	81.38	162.97
78	69.00	83.70	162.40
80	72.18	86.88	161.84
82	75.53	90.23	161.29
84	78.83	93.53	160.72
86	82.05	96.75	160.18
88	85.02	99.72	159.62
90	87.8	102.5	159.08
92	90.9	105.6	158.50
94	94.0	108.7	157.96
96	97.2	111.9	157.41
98	100.2	115.0	156.87
100	103.4	118.1	156.28
102	106.5	121.2	155.70
104	109.5	124.2	155.15
106	112.7	127.4	154.41
108	116.2	130.9	153.69
110	120.0	134.7	152.97
112	124.1	138.8	152.32
114	128.2	142.9	151.49
116	132.0	146.7	150.73
118	135.8	150.5	149.98
120	139.6	154.3	149.28
122	143.7	158.4	148.51
124	147.9	162.6	147.78
126	152.1	166.8	147.02
128	156.7	171.4	146.29
130	161.2	175.9	145.53
135	173.0	187.7	143.65
140	185.2	199.9	141.70

Room Temperatures and Condensing Pressures.— The higher temperatures listed in the refrigerant tables may be considered as the temperatures which exist inside the condenser and in the condensing vapor. With air-cooled condensers the temperature of surrounding air must be lower than the temperature inside the condenser in order that there may be a transfer of heat from the vapor and liquid to the air.

This means that condensing pressures, as measured by a gage connected to the high side, will be higher than pressures that would accompany the temperature of room air were it the condensing temperature. For example, when air temperature around an air-cooled condenser is 80° the condensing pressure for sulphur dioxide may be almost anywhere from 70 to 110 pounds per square inch. The refrigerant tables show that pressures of 70 to 110 pounds correspond to condensing temperatures of about 100° to 124°. So the condensing temperature inside the condenser is from 20° to 44° higher than the temperature of room air, this temperature difference being that which causes heat transfer from the refrigerant to the air.

The higher the pressure in the low side the greater is the density of low-side refrigerant vapor and the more refrigerant is pumped into the condenser by each stroke of the compressor. The resulting greater refrigerant density in the condenser means more heat in the condenser and a higher condensing temperature (and pressure) as compared with temperature of the room air. Higher low-side pressures mean higher evaporating temperatures, so the higher the refrigerating temperature the higher will be the condensing pressure.

Fig. 91 shows condensing pressures such as may exist in air-cooled condensers operating in various

temperatures of surrounding air. The full-line curves apply when evaporating temperatures are about 20°. With evaporating temperatures 15° to

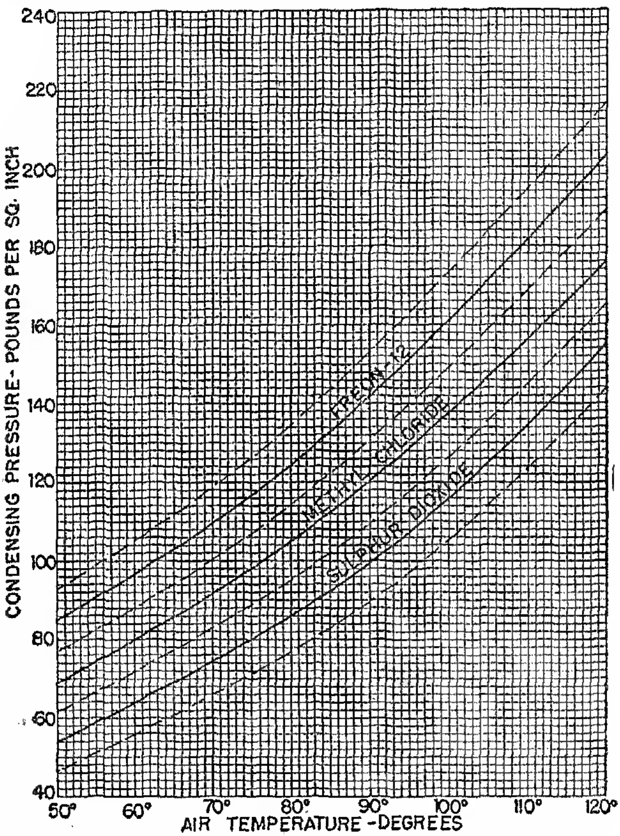

Fig. 91.—Approximate Relations between Room Air Temperatures and Condensing Pressures.

20° lower, the condensing pressures will drop to around the broken-line curve which is underneath the one marked with the refrigerant name, and

with similarly higher evaporating temperatures the condensing pressures will rise to around the broken-line curves above each full-line curve. For example, with air temperature of 80° the condensing pressure for methyl chloride probably would be near 105 pounds, but might easily be anywhere from 95 to 115 pounds, or even run outside these limits to some extent without indicating faulty operation.

CHAPTER 8

TUBING LINES FOR REFRIGERANTS

Suction lines and liquid lines are run with copper tubing, which sometimes is tinned on the outside to provide a desired appearance and sometimes is left with the natural copper surface. The tubing may be of soft temper or of hard temper. The hard tubing cannot readily be bent into smooth curves or turns, but tends to remain straight and true, so is generally used for long or fairly long runs where straightness gives a desired appearance. Soft tubing is easily bent into smooth turns, so is used wherever one or more turns must occur in a run. Hard tubing comes from the suppliers in straight lengths, soft tubing comes either in straight lengths or in coils.

Copper tubing is available with extra thick walls, called type K, with thick walls, called type L, and with walls of standard thickness, called type M. The type K tubing, with extra heavy walls, will withstand higher working pressures than will the types L or M. As shown in the accompanying table, the wall thicknesses of types K, L and M tubing increase with increase of tubing diameter. In another type, called SAE copper tubing, the wall thickness is the same for all diameters used in refrigeration work. Local codes for installation of refrigeration apparatus frequently require certain types of tubing and certain wall thicknesses.

Protection of Tubing Lines.—When running tubing lines which extend outside of refrigerator cabinets or cases every precaution must be taken to insure good support at all points, to protect the tubing from all probable causes of denting and

jamming, and to make certain that there will be no undesirable flow of refrigerant vapor, refrigerant liquid, or lubricating oil.

As shown by Fig. 92, the suction line and liquid line usually are carried along side by side and are supported by clamps placed every two to four feet on straight runs, and within about three inches of both ends of every bend. The tubing is protected from abrasion by wrapping it with friction tape or rubber tape under each clamp.

COPPER TUBING DIMENSIONS

In Inches

Nominal Size	*Type*	*Outside Diam.*	*Inside Diam.*	*Wall*	*Nominal Size*	*Type*	*Outside Diam.*	*Inside Diam.*	*Wall*
1/8	K	0.250	0.186	0.032	3/4	K	0.875	0.745	0.065
	L	.250	.200	.025		L	.875	.785	.045
	M	.250	.200	.025		M	.875	.811	.032
1/4	K	.375	.311	.032	1	K	1.125	.995	.065
	L	.375	.315	.030		L	1.125	1.025	.050
	M	.375	.325	.025		M	1.125	1.055	.035
	SAE	.250	.180	.035					
					1 1/4	K	1.375	1.245	.065
3/8	K	.500	.402	.049		L	1.375	1.265	.055
	L	.500	.430	.035		M	1.375	1.291	.042
	M	.500	.450	.025					
	SAE	.375	.305	.035	1 1/2	K	1.625	1.481	.072
						L	1.625	1.505	.060
1/2	K	.625	.527	.049		M	1.625	1.527	.049
	L	.625	.545	.040					
	M	.625	.569	.028	2	K	2.125	1.959	.083
	SAE	.500	.430	.035		L	2.125	1.985	.070
						M	2.125	2.009	.058
5/8	K	.750	.652	.049					
	L	.750	.666	.042	2 1/2	K	2.625	2.435	.095
	M	.750	.690	.030		L	2.625	2.445	.080
	SAE	.625	.555	.035		M	2.625	2.495	.065

So far as is possible the tubing lines should be located where there is the least possible danger of

their being struck by any passing objects. Where the lines are exposed to possible damage they may be protected, as shown also in Fig. 92, by strips of wood on both sides of the tubing to provide a channel of greater depth than the projection of the tubing from a wall, ceiling or other supporting surface. Additional protection may be provided by covering the tubing and the wood strips with a flat board. When tubing must be run vertically on ex-

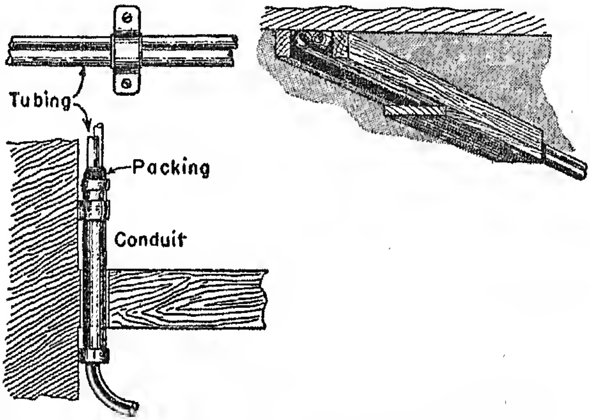

Fig. 92.—Methods of Protecting Refrigerant Tubing Lines.

posed walls both the strips and the covering board should be used to a height of at least five or six feet from the floor.

Where tubing is run through floors or partitions it should be carried in a short piece of rigid steel conduit or pipe, as illustrated in Fig. 92, with the conduit securely clamped and with the tubing held in position by a packing of tape at one or both ends. If the space above a floor is exposed to travel, the conduit or pipe should be run up to a height of five or six feet on a wall or other support.

Tubing lines which are run within walls or in other inaccessible places must be carried through rigid conduit installed in practically the same manner as for electrical wiring. The conduit must be supported with clamps at least every three feet on horizontal portions and every six feet on vertical portions. No connections of any kind may be within the conduit. Valves and all connections between lengths of tubing must be outside the conduit, preferably in steel boxes or cabinets such as used for electrical work.

Tubing is easily pushed through conduit of any ordinary length. On very long runs the tubing may be pulled through with an electricians' steel tape. The end of the tubing must be pinched or hammered to make it tight before being put through conduit. Since condensation probably will occur on the outside of the tubing, within the conduit, provision must be made to drain the runs of conduit.

When tubing lines are run close to steam pipes or hot water pipes the tubing should be protected from the excess heat by liberal thicknesses of insulation, even though the steam or water lines are insulated. Refrigerant lines run out of doors must be equally well protected with insulation.

Practically all of the leakage in tubing lines, and most of the dirt that gets into the lines, come from the joints or connections between lengths of tubing and at the connection of tubing to the apparatus. Consequently, there should be the fewest possible lengths of tubing and, so far as is possible, the tubing should be continuous from one piece of apparatus to the next one. Bends made in the tubing itself are preferable to elbow fittings to which lengths of tubing connect.

Making Tubing Bends.—Soft copper tubing of outside diameters up to and including ⅜ inch is

easily bent by hand, working back and forth along the length of the bend, increasing the curvature a very little at a time, and being very careful not to start any flattened spots. Heavy-walled tubing is easier to bend than that with light walls, and the greater the radius of the bend the easier it is to make without collapsing the tube at any point.

Tubing having outside diameters of ½ inch and larger should be bent with some kind of bending tool. The simplest bending tool is a closely coiled steel spring as long or longer than the bend and having an inside diameter not much larger than the outside diameter of the tubing. With a suitable spring slipped over the tubing it is easy to form a smooth curve, after which the spring is pulled off the tubing. The larger sizes of tubing usually are bent with a machine which consists essentially of a grooved and curved form into which the tubing is pressed by a grooved roller operated through a lever.

Tubing Traps and Locks.—Wherever tubing lines do not run vertically or in a generally vertical direction it is desirable that they always have some slope downward in the direction of the condensing unit and that they never turn even slightly upward after leaving the evaporators on their way to the condensing unit. Upward turns in suction lines form oil traps which prevent return of lubricating oil to the compressor, while upward turns in liquid lines may allow vapor locks or air locks.

Fig. 93 illustrates a suction line with upward and downward slopes. Oil will tend to remain on the evaporator side of any upward bend, and may be trapped to form a pocket in the bottom of any downward bend. If a liquid line turns upward and then downward again, vapor may form in the top of the bend during periods when there is no flow, and the

vapor lock will make it more difficult to start the next flow. If there is air in the system it will remain in any such upward bends.

At or near the condensing unit the refrigerant tubing lines sometimes are formed into loops which provide a certain flexibility for absorbing vibration of the condensing unit without transmitting it to the tubing lines. Such loops should be horizontal, as shown at the left in Fig. 93, so that there is a con-

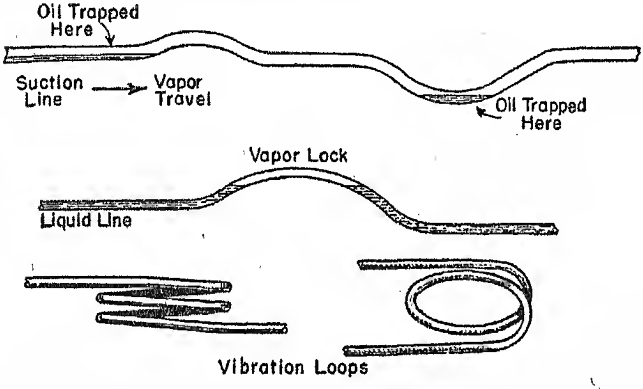

Fig. 93.—How Locks and Traps May Be Formed in Tubing Lines.

tinuous downward slope toward the condensing unit. If they are inclined, as at the right, oil pockets will form in the suction line and vapor locks in the liquid line.

At *A* in Fig. 94 the suction lines from two evaporators run horizontally from each evaporator to their junction with the common suction line. Condensed refrigerant from either evaporator may easily flow over into the suction line near the other evaporator and affect the temperature of the thermostatic bulb for the expansion valve of that other evaporator, especially during periods when the com-

pressor is idle. The result will be that either evaporator may be partially controlled by conditions at the other one rather than solely by its own requirements. The difficulty may be avoided by placing downward bends, as in diagram *B*, between the location of each thermostatic bulb and the junction of the two suction lines with the common line. Condensation from either evaporator then will flow downward to the common suction line, and would have to flow upward to reach the thermostatic bulb of the other evaporator.

At *A* in Fig. 95 condensed refrigerant from the upper evaporator will run down through the suction

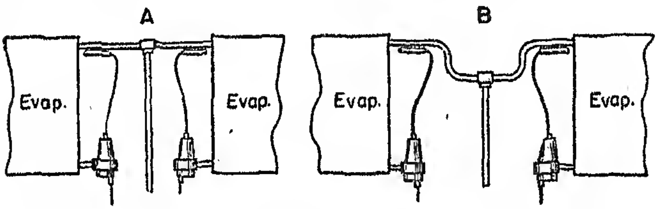

Fig. 94.—Incorrect Suction Line Connections at *A*, and a Correct Method at *B*.

line to the junction, and then is just as likely to flow to the left and affect the thermostatic bulb for the lower evaporator as to flow to the right into the common suction line. Thus the expansion valve for the lower evaporator may be affected by conditions existing at the upper evaporator. The difficulty is avoided by running the vertical portion of the suction line on below the junction point, as in diagram *B*, so that condensation from the upper evaporator will continue downward past the junction with the suction connection for the lower evaporator, and will go into the common suction line rather than affecting the lower expansion valve.

Whenever a suction line extends horizontally or

upward from the location of any one thermostatic bulb to another evaporator, it may be possible for condensation from that other evaporator to affect the temperature of the first thermostatic bulb. The remedy is to provide a downward suction connection either at the same point as the upward connection, or before reaching the upward connection.

Tubing Fittings.—A fitting is any device which allows the connection of tubing or piping to any parts of the refrigeration apparatus, or which

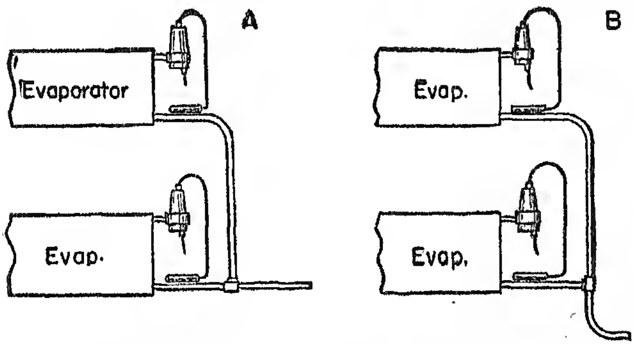

Fig. 95.—At *A* Conditions at the Upper Evaporator May Affect the Lower Unit. At *B* the Fault Is Avoided.

allows connecting together two or more pieces of tubing or piping. A few of the more common types of fittings are shown by Fig. 96. Although various manufacturers use different names for a fitting which serves a given purpose, the following meanings are generally understood.

A *connector* is a fitting which allows connecting together two pieces of tubing or pipe during assembly of the apparatus, but which cannot readily be disconnected because of the fact that turning any portion of the fitting tightens some threads while

loosening others, with the result that none of them can be completely unscrewed without disturbing other parts of the system. A *union* is a fitting that joins two lengths of tubing or pipe and which allows either one to be disconnected without disturbing the other or any parts which are connected.

A *reducer* allows connecting tubing or piping of

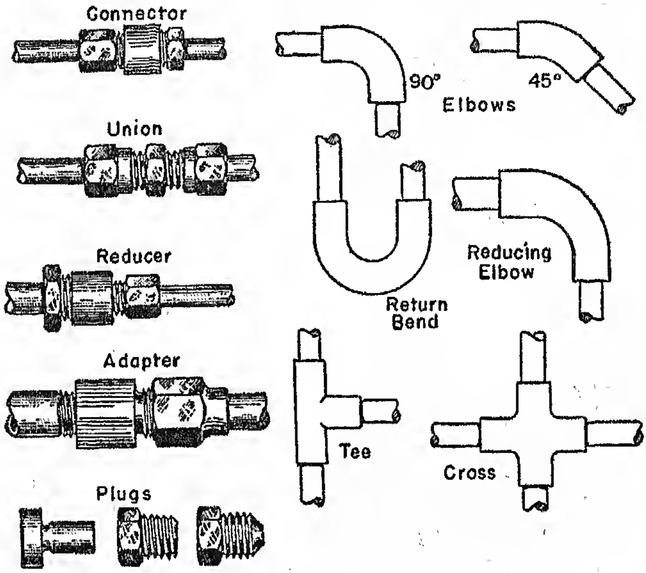

Fig. 96.—Types of Tubing Fittings.

one diameter to tubing or piping of a different diameter. An *adapter* allows connecting tubing and piping together, or allows using one style of joint on one side of the adapter and a different style on the other side.

Elbows are fittings which allow making short bends between runs of tubing or piping. Usually they are used where the turn must be too short to

be made by bending the tubing itself. Elbows usually are available for either 90° or 45° turns, and sometimes for 22½° turns. A *reducing elbow* allows connecting together two different diameters of tubing or piping. A *return bend* is a sort of elbow that makes a turn of 180°, allowing connection of parallel lines.

A *tee* is a fitting which allows one line to continue straight along while another is connected to it at right angles. The straight-through line is called the run and the other is called the branch line. A *cross* allows a four-way connection or a connection between two lines which come together at right angles. *Plugs* allow closing or sealing any opening of any

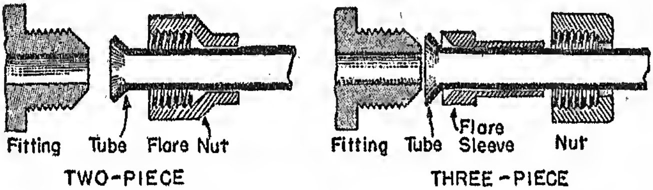

Fig. 97.—Two Styles of Flared Tubing Connections.

fitting, no matter for what style of connection the fitting is designed.

Tubing Connections.—Gas-tight and liquid-tight joints are made between the ends of tubing and fittings or other parts of the apparatus in various ways, some of which are illustrated by Figs. 97 and 98.

Fig. 97 shows in a general way the construction of two styles of *flared* tubing connections. With the two-piece flared connection the end of the tubing first is passed through the flare nut, and then the end of the tubing is spread or flared at an angle of 45° so that it fits into a similarly shaped recess in the nut and fits over the tapered end of the fitting.

Screwing the nut onto the fitting allows these parts and the flared end of the tube to make a tight joint.

In the three-piece flared connection there is an extra sleeve slipped over the end of the tube before the tube is flared. The recess for the flared end of the tube is in the end of this sleeve, and on the outside of the sleeve is a collar against which the nut is screwed in drawing the joint tight. The twisting action of the nut is taken by the sleeve rather than by the flared end of the tube.

Fig. 98 shows connections in which the end of the tubing is left straight and is held by sweating or soldering between the outside of the tubing and the inside of the fitting itself or the inside of a special

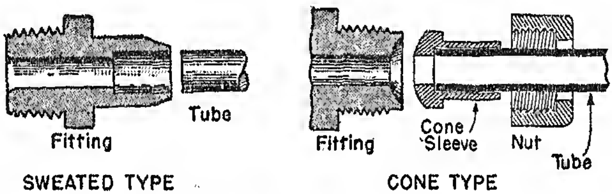

Fig. 98.—Types of Connections Made with Straight Ends on the Tubing.

cone sleeve. The *sweated* type of fitting, into which the tubing fits directly, is commonly used for all diameters of tubing but especially for diameters of ⅝ inch and larger. In the cone type of connection the end of the tubing is sweated into the cone sleeve, after which the sleeve acts much like the sleeve in the three-piece flared connection except that the recessed opening now is in the fitting.

Flared connections may be used only with soft temper tubing, since hard tubing cannot be spread or flared without splitting or breaking it. The sweated or cone type connections may be used with either soft or hard tubing.

Cutting the Tubing.—For any style of connection it is essential that the end of the tubing be cut off perfectly square. Otherwise the solder will not be evenly distributed in a sweated joint, and a flared joint either will fail to seat tightly or will seat so unevenly as to allow leakage. Cutting may be done with a hack saw having 32 teeth per inch, or with a regular tubing cutter which consists of a grooved portion to hold the tubing and a knife-edge wheel pressed against the tubing while the cutter is rotated.

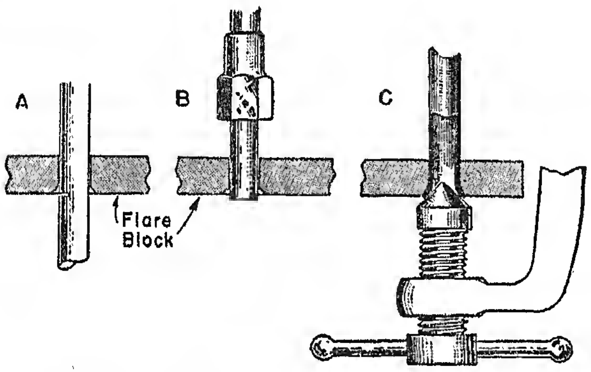

Fig. 99.—Flaring the Tubing with a Flare Block.

To prevent particles of metal from getting inside the tubing the end being cut should be pointed downward, especially when using a hack saw. Tubing sometimes comes sealed and with a partial vacuum inside. If cutting is to be with a saw the end of the tubing first should be broken off with pliers to relieve the vacuum and prevent metal particles from being sucked inside the tube.

A tubing cutter turns the end of the tubing inward to form a burr which must be removed with a reamer which often is attached to the cutter, with

a small rat tail file, or with the blade of a knife. Inward projections from sawing are similarly removed. The outside of the tubing at the cut end should be smoothed and cleaned with fine steel wool or with sand cloth, but not with a file because there is danger of removing so much metal as to leave the end out of round.

Flaring the Tubing.—The steps in one method of flaring soft tubing are shown by Fig. 99. The principal tool is a flare block in which are holes of several diameters through which may be passed

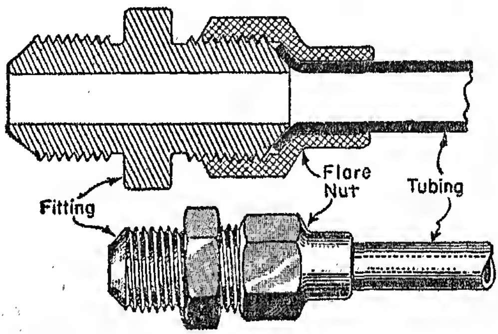

Fig. 100.—A Completed Connection Made with Flared Tubing.

different sizes of tubing. The holes are recessed or tapered at one end to form the correct angle of flare. Flare blocks usually are split and hinged so that they may be opened to receive the tubing, then clamped to hold it securely.

As shown at *A* in Fig. 99, the flare block may be used as a guide to cut the end of the tubing squarely with a hack saw. The next step, at *B*, is to place the flare nut over the cut end of the tubing, bring the end of the tubing through the block far enough to make a flare of full diameter, then clamp the tubing in this position. As shown in Fig. 100, which

illustrates a completed connection, the outer diameter of the flare should be as great as possible while still allowing clearance for the threads of the nut.

The final step, shown at *C* in Fig. 99, is to turn the cone-shaped end of the flaring tool into the tubing just tightly enough to form the tubing at the flare angle, but not so tightly as to deform or squeeze the tubing to make it hard and brittle. Other types of flaring tools do not make use of the tapered member which is screwed against the tubing end, but instead have plungers which fit into a guide hole and are lightly tapped with a hammer while being rotated to flare the end of the tubing.

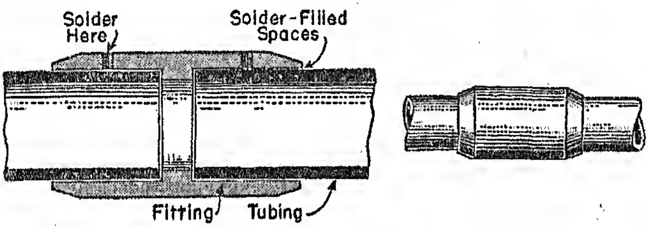

Fig. 101.—A Sweated Type of Tubing Connection.

Sweated Connections.—In a sweated connection, as shown by Fig. 101, the opening for the tube in the fitting is slightly larger than the outside diameter of the tubing to be used, leaving a small cylindrical space between fitting and tubing. The fitting and the end of the tubing are heated to a temperature which liquefies solder applied to them. When any liquid reaches any part of a small opening or space the liquid is drawn into and through the space by capillary action. Hence the liquid solder fills the entire space between fitting and tubing, and when the parts cool, the joint is mechanically strong and completely tight for gases and liquids.

The end of the tubing is cut and trimmed as pre-

viously described. The end must be truly cylindrical to insure even distribution of solder, which will not occur if the space is larger at some places than at others. If the end of the tubing has been deformed it is rounded with a sizing tool, which has a long, slender taper.

The inside of the fitting, and the outside of the tubing for the depth to which it will enter, are cleaned and polished with fine steel wool or with sand cloth. A thin coating of flux then is applied to the inside of the fitting and to the outside of the tubing, the tube end is inserted into the fitting, and any excess flux wiped off the outside of the joint. The parts should be at a temperature of 70° to 80° to insure good distribution of the flux.

The joint now is heated with a blow torch, and at intervals the flame is taken away while wire solder is touched to the point at which it should enter. With some types of fittings (Fig. 101) the solder is fed through holes midway of the tubing space, while in others the solder is fed from the end of the joint. When the parts are almost hot enough, the solder will melt. Then a little additional heating will allow it to be drawn into the spaces of the joint. Solder should be fed in until a line of it shows all the way around the outer end of the joint, between the fitting and the tubing. Any excess solder should be removed, before it hardens, with a small camel hair brush. Flowing of the solder sometimes may be assisted by slightly twisting or lightly tapping the fitting, and on large joints by applying solder first on one side and then on the opposite side of the joint. The parts should not be moved or stressed in any way until the solder has set for at least one-half minute after the joint has been filled.

CHAPTER 9

REMOVING WATER, AIR AND DIRT

Within the evaporator, compressor, condenser, receiver and tubing of a refrigeration system we must have a refrigerant. Because moving parts of the compressor require lubrication we must have oil. But in addition to the refrigerant and the oil, which we must have, there frequently are small quantities of water and of air, both of which are wholly undesirable and harmful.

Moisture and air often enter together, because in all air there is more or less water vapor along with the oxygen, nitrogen and other gases of which air is composed. Moisture and air may enter through leaky shaft seals, through faulty tubing connections, through defective gasketed joints, and through many other kinds of leaks. Moisture and air often get into the system during service operations which are incorrectly performed, and during installation of the equipment. Water or moisture may come in with refrigerants or oils which have not been well freed of water, or which have been allowed to gain water through contact with air.

Air, which consists of gases that cannot be condensed in the refrigeration system, causes excessively high pressures in the high side of the system, and reduces the operating efficiency. Water causes more serious troubles.

Water does not dissolve to any great extent in Freon-12, but tends to separate and remain apart from this refrigerant. Consequently, the separated water is likely to freeze into ice and clog the small openings in expansion valves, in capillary tubes, and at any restrictions in the system. Ice in a re-

frigerant feed valve stops flow of refrigerant. Then the evaporator and valve warm up, the ice melts, and refrigeration once more takes place—only to again be stopped as more ice forms. Such intermittent refrigeration is an indication of excessive water in the system. Clogging due to particles of dirt reduces or stops refrigeration completely until the dirt is removed. Clogging due to water is intermittent, while that due to dirt is permanent, or continuous.

Water is highly soluble in sulphur dioxide, and once mixed the two do not readily separate. Consequently there is little or no danger of ice formation in a system employing sulphur dioxide. Sulphur dioxide and water combine to form small quantities of sulphurous acid, which quickly and seriously corrodes the metals used in refrigeration apparatus. Corrosion of metals will occur with any refrigerant when there is water in the system, but the action is very rapid with sulphur dioxide and much slower with Freon-12 or methyl chloride. None of these refrigerants attack metals of the refrigeration system when there is no water present or when the quantity of water is negligible.

Water emulsifies with lubricating oil, meaning that the two form an intimate mixture of exceedingly fine globules of the liquids. This effect, commonly called *sludging* of the oil, greatly reduces the lubricating ability of the oil. Water in a refrigeration system tends also to make diaphragms and bellows lose their elasticity and become harder and more brittle.

Refrigerants, oils, and chemicals in general which are free of water are called *anhydrous*. Spaces which have been freed of water are said to be *dehydrated*. Refrigerant tubing, especially the smaller sizes which come in rolls, frequently is

dehydrated and has the ends sealed to exclude moisture-bearing air. The seals should not be broken until just before the tubing is to be installed. All types of control valves, filters and other parts come from manufacturers and from service organizations completely dehydrated and with all openings capped or plugged. These should not be opened until they are to be installed.

When a job of installation or servicing must be left only partially completed for an hour or more, all openings at valves and other units should be plugged or capped, and the ends of all soft tubing

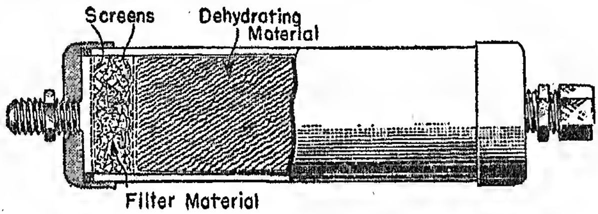

Fig. 102.—Construction of One Type of Dehydrator.

sealed closed by pinching the ends with pliers or by hammering them securely closed. These sealed ends later are cut off.

Dehydrators.—Such quantities of water as ordinarily get into a refrigeration system may be removed by causing the liquid refrigerant, or sometimes the refrigerant vapor, to pass repeatedly through some material that has a strong affinity for water and which gradually dehydrates the refrigerant to leave it practically free of water.

The dehydrating material is held in a dehydrator constructed along the lines shown by Fig. 102. At each end of a sack or tube of the dehydrating material is a metallic screen. Outside the screens are filter pads of metallic wool or glass wool held in

place by other screens. Tubing or piping connections at each end are kept sealed with caps or plugs until the dehydrator is to be inserted in the refrigerant line.

Among the commonly used dehydrating materials are activated alumina, which is a form of aluminum oxide, also calcium sulphate, and silica gel, which is a form of silicon. In all of these materials there are pores microscopically small into which the water is drawn and in which it remains until driven out by heat during the process of reactivating the materials. No chemical changes occur in these materials. The water is retained by the action called *adsorption*. Another common dehydrating material is calcium oxide, which disintegrates or powders as it absorbs water and which is replaced with a fresh charge after being used. Still another material is anhydrous calcium chloride, which also absorbs rather than adsorbs the water, and which is replaced after being used.

In all dehydrating materials there is more or less increase of resistance to flow of refrigerant through them as they take up water. This resistance, which acts as a restriction to flow and causes a change of pressure, may become so great as to cause actual refrigeration at and just beyond the dehydrator. The lowered temperature ordinarily causes condensation of water droplets on the outside of the tubing, and may cause frosting of the tubing. Excessive condensation, or frosting, indicates that the dehydrating material should be reactivated or replaced.

Dehydrators usually are temporarily inserted in the liquid line, or sometimes in the suction line, after the equipment has been installed and tubing connections completed, also after charging the system with new refrigerant and after various other

service operations during which moisture may have entered. The pads in the dehydrator cause it to act as an effective filter for removal of dirt and any loose solid matter from the system during the dehydration process.

Attaching a Gage.—The first step in installing a dehydrator is to connect a compound gage to the service valve on the suction side or low side of the compressor. To attach a compound gage, or a pressure gage when required, proceed as follows:

1. Remove from the service valve the cap that protects the valve stem. Be careful not to lose any washers or gaskets that are under the cap.

2. With a solid wrench or a smooth-jawed adjustable wrench that correctly fits the end of the valve stem try turning the stem to make sure that it is in the fully opened position or in the normal operating position. This position usually is reached with the stem turned all the way to the left or counter-clockwise. In the open position the gage port is securely closed. When in position to tightly close the gage port the valve is said to be *back-seated.*

3. Remove the plug or cap from the gage opening of the service valve.

4. Usually the gage may be screwed directly into the gage port, but sometimes it is necessary to use adapters, unions, elbows or other fittings, or short lengths of tubing when there is too little space for the gage near the valve. To prevent leaks, a little red lead should be placed on the male threads of the gage and of any fittings. This is especially necessary if the threads are worn or loose from much use.

5. Do not as yet screw the gage tightly into the port opening, or, if connections are used, leave the threads at the gage slightly loose and tighten the

other joints, including the one at the gage port on the valve.

6. Crack the service valve by turning the stem just a little ways from the back-seated or open position. This allows refrigerant vapor or gas to escape from the system and clear out, or "purge," air that is in the connections between service valve and gage. Immediately tighten the gage, or tighten the connection that has been left loose. The gage now is ready for use.

Reference to Fig. 55 will show that with the gage connected and the service valve cracked the gage will read pressures or vacuums with the compressor connected to the suction line or discharge line, so this is the position of the service valve for gage readings with the compressor running. The valve should be cracked only enough to obtain a gage reading and allow as little vibration as possible of the gage pointer. Too much opening of the valve allows the sudden pulses of pressure from the compressor to vibrate the gage pointer excessively.

If the service valve is turned all the way to its closed position the gage will remain connected to only one of the valve openings, and will measure pressure or vacuum only in parts connected to that opening.

To remove a gage from a service valve proceed as follows:

1. Turn the service valve stem to the fully opened or back-seated position, thus shutting off the gage port.

2. Remove the gage and any extra connections which have been used.

3. Replace the plug or cap for the gage port.

4. Try turning the nut that presses on packing around the stem in most service valves. This nut

should be tight to prevent leakage around the stem.

5. Replace the protective cap for the valve stem, also any washers or gaskets.

6. Test for leaks at all connections that have been disturbed. The subject of leak tests is covered in another portion of this book.

Attaching a Dehydrator.—A dehydrator usually is connected into the refrigeration system between

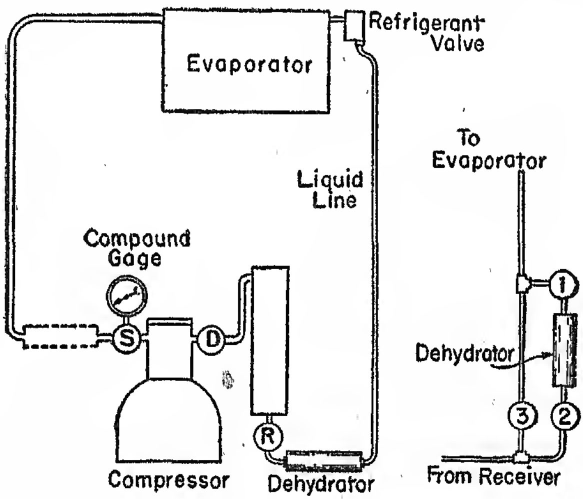

Fig. 103.—Points at Which a Dehydrator May Be Connected.

the liquid line and the service valve which is at the outlet from the condenser or receiver, as shown by Fig. 103. Sometimes the dehydrator is placed between the suction line and the suction service valve at the compressor. To place a dehydrator in the liquid line proceed as follows:

1. Close the receiver service valve, *R* in Fig. 103.

2. Attach a compound gage at the suction service valve, *S* in Fig. 103.

3. Run the compressor until the gage shows a slight vacuum. Then carefully open the receiver service valve *R* to make the gage show between zero and a pound or two of pressure, and close valve *R*. This insures that there is a pressure slightly above atmospheric in the part of the system where the dehydrator is to go, so that air will not be drawn into the system and so that there will be a negligible escape of refrigerant.

4. Make sure that the dehydrator and any necessary fittings and connections are ready for fast work in completing the attachment. Then disconnect the liquid line from receiver valve *R*, close the liquid line with a snugly fitting wooden plug, and attach one end of the dehydrator to the receiver valve.

5. Open the receiver valve just long enough to drive all air out of the dehydrator and let refrigerant come through, then remove the wooden plug and quickly attach the liquid line to the free end of the dehydrator. With the receiver valve opened the system now is ready for operation, during which the dehydrator will remove moisture.

To remove the dehydrator proceed as follows:

1. Close the receiver valve, run the compressor to obtain a slight vacuum, then open the receiver valve until the compound gage shows a small positive pressure.

2. Disconnect and remove the dehydrator.

3. Attach the liquid line to the receiver valve, but leave the connection loose.

4. Open the receiver valve just enough to drive air out of the liquid line connection, then quickly tighten the joint. Open the receiver valve for normal operation.

5. Test for refrigerant leaks at all joints that have been disturbed.

As shown by the small sketch at the right-hand side of Fig. 103, a dehydrator may be permanently installed in a refrigeration system, paralleling a section of the liquid line. For normal operation shut off valves *1* and *2* are closed, and *3* is opened. To use the dehydrator valve *3* is closed and valves *1* and *2* are opened, thus forcing refrigerant liquid to pass through the dehydrator on its way from the receiver or condenser to the evaporator.

Using the Dehydrator.—A dehydrator may be left in refrigeration system anywhere from three or four hours to three or four days of normal operation. If the liquid line frosts beyond the dehydrator after a few hours, the dehydrator should be removed for recharging or reactivating, then replaced and operation resumed. Every time there is frosting or much water condensation on the outside of the liquid line this procedure should be continued. In any case the dehydrator should be removed after 24 to 48 hours of operation and the dehydrating material examined. Materials which undergo no physical change will appear or feel wet after taking up water, while others will reduce to smaller granules or to powder as they absorb water. Dehydrating material which becomes clogged with oil, or which becomes dirty, should be replaced with fresh.

No dehydrator will remove all water from a refrigeration system, but when recharged or reactivated at suitable intervals during a long period of operation it will reduce the water content to an amount which is not harmful. Dehydrators usually are not kept in operation for long enough to do a good job. If only a few hours are available, the doors of a refrigerator or other refrigerated space may be left open so that the compressor will run practically all the time and thus keep driving the refrigerant through the dehydrator.

Recharging and Reactivating of Dehydrators.—The chief characteristic of any dehydrating material is its strong affinity for water or moisture. If such materials are exposed to moist, humid air they quickly will take up water from the air and their efficiency will be greatly reduced or completely destroyed. Fresh material should be kept tightly sealed from air until it is to be used, and dehydrators should be recharged only where the surrounding air is reasonably free of moisture or where the humidity is low. The higher the temperature in a room the lower is the humidity and the less is the wetting effect of air with a given moisture content, so recharging of dehydrators indoors should be done where the temperature is high.

After each period of use in a refrigerating system a dehydrator should be recharged or reactivated immediately, then tightly sealed and laid away. Allowing water-soaked dehydrating material to remain in the dehydrator not only disintegrates the material but may damage the metal parts of the unit.

Activated alumina, silica gel and calcium sulphate are reactivated by removing them from the dehydrator and heating them to a temperature of 250° to 300° F. for several hours to drive out the water that has been adsorbed. This work may be done in an oven, or hot air may be circulated through the cartridge. The dried material then is replaced in the dehydrator with the least possible delay so that moisture will not be taken up from surrounding air. Manufacturers of other dehydrating materials issue instructions for reactivation or for quantities to be used in replacements.

Pumping Down the System.—The procedure previously described for reducing the low side pressure to between zero and about two pounds for attaching

a gage usually is called "pumping down" or "balancing the pressure." This generally is required before opening any connections in a refrigerating system that is in operation, and thus precedes most small repairs, replacements of parts, and cleaning operations. The temperature of the evaporator first will drop as refrigerant is evaporated. Then, as practically all refrigerant is evaporated from beyond the closed receiver service valve, the temperature will rise—thus indicating that the evaporator, the refrigerant feed valve, and the liquid line are almost clear of refrigerant and safely may be opened.

To operate the compressor in obtaining the necessary low pressure it usually is necessary to hold closed or block closed the switch in the cycling control. When the ends of refrigerant tubing lines, or openings of any valves or other parts are to be exposed for even a few moments it is highly desirable to temporarily seal these openings with wooden plugs to prevent entrance of air and moisture. It is a general rule, when re-connecting the parts, that the joint farthest from the refrigerant supply (as in the receiver) should be left loose while all others are tightened and a small quantity of refrigerant allowed to pass through the connections to force out any air that is in them. Then the loose joint is quickly tightened.

Cleaning Strainers or Filters.—To remove a strainer or filter the system is pumped down, then the strainer or filter is removed for cleaning, while open tubing remains plugged. When the strainer or filter is opened, care must be used not to damage gaskets or the surfaces on which they make sealing contact. Wire strainers are wiped or lightly scraped, after which low-pressure air may be blown through from the side on which dirt does *not* collect. Metal

wool and glass wool filters may be washed in carbon tetrachloride or acetone. All joints must be made securely tight when reassembling.

Strainers and filters should be cleaned after the first few hours of operation of a newly assembled or repaired system, and cleaned again after a few more days of operation. Clogged liquid line strainers and filters act as restrictions in the system, allow a pressure drop with accompanying evaporation, and indicate their condition by frosting or excessive condensation on the strainer and the liquid line just beyond it in the direction of refrigerant flow.

Purging of Air.—Whenever any part of a refrigeration system is opened during servicing or repair operations, and often when refrigerant or oil is added, a small quantity of air gets into the connections and parts. The removal of this air, or most of it, is called *purging*.

Air does not mix with liquid refrigerant, but it does remain intimately mixed with refrigerant gas in the condenser, receiver, and compressor discharge line. The basic principle of purging is release of some of the air and gas mixture from one or more of these parts. As the mixture is released, additional pure refrigerant evaporates and displaces the air mixture, thus reducing the percentage of air in the space above the liquid until the amount of air remaining is too small to cause trouble.

Were there nothing but refrigerant and oil in the system, with no air or foreign gases, the internal temperatures and vapor pressures would be those listed in the refrigerant tables. Air, and other gases which are not condensed, cause the low-side pressure to rise above the pressure corresponding to the temperature inside the system. The greater the quantity of air the greater will be the difference

between actual pressure and normal vapor pressure while the compressor is idle and after the internal pressure and temperature have become of constant or steady values.

With an air-cooled condenser the high-side pressure with the compressor running will be above that which would correspond to temperature of surrounding air. But with a water-cooled condenser and automatic water-flow regulating valve operated from high-side pressure, any increase of pressure will allow more water flow, so the action is to increase the rate of water flow while maintaining a practically constant high-side pressure. Thus, with a water regulating valve, the presence of air is indicated by increased water consumption rather than by a rise of high-side pressure.

Were any refrigeration system allowed to remain idle for so long that external and internal temperatures became equal it would be possible to measure high-side pressure and compare it with room temperature, assuming room temperature and internal temperature to be equal. This would call for a long shut down. Some of the larger commercial systems have provision for measuring liquid temperature in the receiver with a thermometer inserted into a well. Then actual temperatures and internal pressures may be compared. A difference of more than 5° between actual liquid temperature and normal temperature for actual high-side pressure indicates that purging is required.

For any given refrigeration system having an air-cooled condenser there are certain normal relations between high-side pressure, low-side pressure, and room air temperature. For some one type of equipment using Freon-12 these relations might be as shown by full-line curves in Fig. 104. The relations are different for different types and models of equip-

ment, so must be known or else determined while the system is known to be operating correctly or normally. Purging is called for when high-side pressures become more than about 15 per cent greater than those which would be normal for the

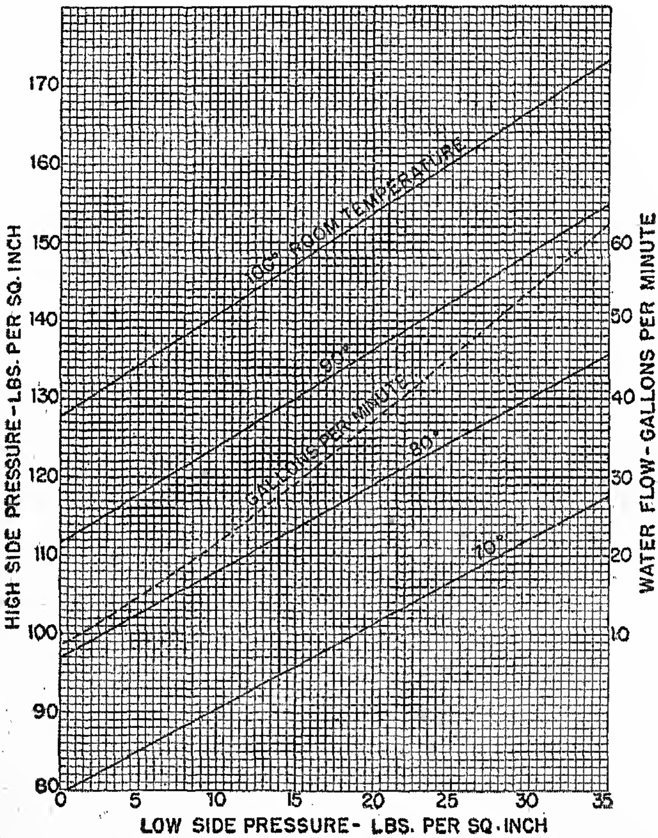

Fig. 104.—Typical Relations between Low-side Pressures and High-side Pressures with Air-cooled Condensers, or Water Flow with Water-cooled Condensers.

existing room temperature and the measured low-side pressures.

The broken-line curve of Fig. 104 shows the relations which might exist in a particular system between water flow in gallons per minute for a water-cooled condenser, and measured high-side and low-side pressures. If the rate of water flow is more than about ten per cent above normal it indicates that purging may be required.

Methods of Purging.—From what point or points of the system air may be purged will depend on where there are valves or connections which may be opened. Air may be released from the top of a combined condenser-receiver, from the top of a separate receiver, from the discharge line between compressor and condenser, or from the top of a high-side float chamber.

If there is a purging valve in the upper part of a receiver this valve, naturally, will be used to release air. Air may be released through the discharge service valve on the compressor, valve *D* in Fig. 103. This is done by first making sure that the valve is fully opened or back-seated to shut off the gage port, then removing the gage plug and turning the valve stem a little way toward the closed position for a few moments at a time—thus allowing air to escape through the gage port.

With Freon, methyl chloride, and other non-irritating refrigerants small quantities of air and refrigerant gas may be allowed to issue directly into the room air, but it is preferable to connect a long rubber tube to the purge valve or the gage port of the service valve and extend the tube to outdoor air. If there is no valve at a high point in the system, purging may be done by loosening a tubing connection just far enough and long enough to allow escape of a little air at a time.

Sulphur dioxide systems must not be purged into the room air and preferably not to outdoor air. A length of tubing connected to the purge valve or service valve may be run into a drain or sink, and purging done while water is freely flushed around the end of the tube. Sulphur dioxide systems usually are purged through a length of tubing whose end is placed in a solution of lye in water. This solution attacks metals, so must be in a container of glass, enameled ware, wood or fibre. If a glass bottle is used it should be set in a pail of cold water or ice and water to absorb heat produced when mixing the lye and also by action of the sulphur dioxide. The solution is made by adding slowly four ounces of lye for each quart of cold water.

The refrigerant gas and air should be released slowly into the lye solution. The solution will absorb the sulphur dioxide, leaving only air bubbles to rise to the surface. Too rapid purging will allow refrigerant to rise and escape into the air. The end of the tube must be withdrawn from the solution immediately after closing the purge connection or valve, otherwise liquid will be sucked into the tubing and possibly into the refrigeration system.

With the purging connections completed the operation is carried out as follows:

1. Close the receiver valve and start the compressor.

2. Pump the low-side pressure down to five or ten pounds per square inch, but not to zero gage, then stop the compressor.

3. Allow the system to remain idle until the high-side pressure and the temperature around the condenser become constant, with no further drop.

4. Open the purging valve or connection a very little ways, and after a few seconds close it again.

The air-gas mixture must be released very slowly so that evaporated vapor pushes it out of the system with the least possible disturbance of liquid inside the condenser or receiver.

5. Repeat the opening and closing of the purging vent until a noticeable amount of refrigerant commences to escape. Freon-12 smells somewhat like carbon tetrachloride when there is a concentration of more than 20 per cent by volume of the refrigerant in air. Methyl chloride by itself has a faintly sweetish odor, but when it contains acrolein the odor is irritating. The odor of sulphur dioxide is quickly noticed, even with small amounts of the gas. Evaporation of refrigerant in the condenser or receiver, after most of the air has been released, causes these parts to become noticeably colder—thus indicating that purging has been carried far enough.

There always is a chance that excessive purging or incorrect methods of purging will allow the escape of a considerable amount of refrigerant from the system. Consequently, after purging, the action of the system should be watched for evidences of too little refrigerant. The principal symptoms include abnormally low pressures on both the low side and high side of the system, excessively long operating periods of the compressor, lack of frost on the evaporator, and general difficulty in maintaining desirably low refrigerating temperatures.

Protection from Refrigerants.—Whenever you open any connection in a refrigeration system that has been in operation and which contains refrigerant, you should wear goggles or glasses with large lenses to protect your eyes from possible injury. Liquid refrigerant that gets onto an eyeball freezes the water that always is in the eyes. The treatment is immediate washing with plenty of water, then examination by a physician. Refrigerant splashed

onto your skin may freeze small local areas. The treatment is the same as for frost bite due to any other cause.

Leaks of Air or Refrigerant.—The need for purging may indicate that air is entering the system through leakage at some tubing connection, at some gasketed joint, or around the stem or packing of some valve. A shortage of refrigerant may mean that some of it has escaped through leaks. Leaks should be looked for at every point where two parts or two pieces of any part come together, not only at tubing connections and gasketed joints which occasionally are opened, but wherever there is a supposedly permanent soldered or welded connection.

Outward leaks of refrigerant may occur in the high side of any system, for the internal pressures always are above atmospheric. Outward leaks may occur also in the low sides with Freon and with methyl chloride, whose low-side pressures usually are above atmospheric. Inward leaks of air frequently occur in sulphur dioxide systems on the low side, for operation usually is below atmospheric pressure. Outward leaks of refrigerant frequently are located by looking for oil films formed where oil carried through the system with the refrigerant has escaped and remained unevaporated at the point where there is a leak.

Leakage of Freon-12.—Outward leaks of Freon-12 are detected and located with the help of a device called a *halide torch*. The name *halide* applies to certain chemical compounds containing fluorine, chlorine, iodine or bromine, of which one is Freon-12 whose chemical name is *dichlorodifluoromethane*. One style of halide torch is shown by Fig. 105. It is much like a gasoline blow torch to which has been added an "exploring tube" through which is

drawn air by injector action from points at which leakage is suspected. The torch is heated with denatured alcohol, or sometimes with acetylene gas. Near the place where air is drawn into the alcohol flame is a copper screw or plate heated red hot by the flame. If the slightest trace of Freon comes through the exploring tube the normally blue alcohol flame changes to green, thus indicating that the free end of the exploring tube is being held near a point of leakage.

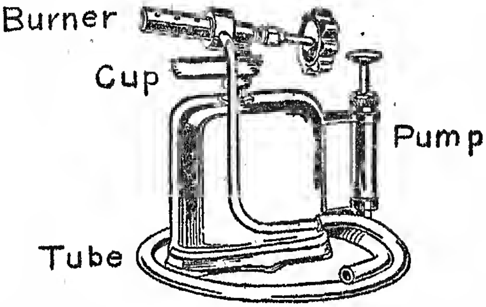

Fig. 105.—A Halide Torch with Exploring Tube.

When a system is to be tested for leaks the compressor is stopped and the low-side pressure brought up to about ten pounds. The rise of low-side pressure may be hastened by opening cabinet or refrigerator doors. After every part of the apparatus has been tested at this pressure, the pressure may be brought up to 35 or 40 pounds on the low side and the tests repeated.

The halide torch should be filled with denatured alcohol where there is no possibility of refrigerant fumes getting into the torch, using no filling utensils that have been used for handling refrigerant, then pumping up a moderate torch pressure while still

in the place where there can be no refrigerant fumes in the air. The torch is lighted like a gasoline blow torch; partially filling the cup with alcohol by opening the torch valve, letting the burner tube heat, then opening the torch valve just before the cup liquid burns out. Lighting usually is easier with the end of the exploring tube pinched closed. Adjust the torch valve so that the flame extends just beyond the burner tube. Action of the torch may be checked by holding the end of the exploring tube where there is known to be some Freon gas and noting whether the flame turns green. A flame that is yellow or white indicates that the exploring tube is clogged.

Now go over the apparatus being tested, holding the free end of the exploring tube close to every joint and passing it slowly all the way around the joint. It takes some time for any escaping refrigerant gas to be drawn through the exploring tube into the torch flame, so this part of the work must not be hurried. The worse the leak, and the greater the concentration of refrigerant carried into the torch, the darker will be the green of the torch flame. Large leaks may turn the flame to bright purple, or may even extinguish it by keeping air and oxygen from the flame.

With very large leaks all the surrounding air may contain so much Freon that the torch flame remains green all the time. This may happen also where there is poor ventilation. Then it becomes necessary to test the suspected joints with a soap and water solution. This solution should be made of about the consistency of liquid hand soap, and should lather freely with a brush. A little glycerine added to the soap solution helps maintain it without drying so quickly on the joints. With a small brush the soap solution is painted all the way around every

suspected joint after the joint has been wiped free of any oil or dirt which may have collected.

Leaks are indicated and located by bubbles formed in the soap solution. Sometimes it takes as long as a full minute for bubbles to appear. Sometimes the leak is so bad as to blow the solution away without forming bubbles. Inaccessible points may be watched with the help of a small pocket mirror and, if necessary, a flash lamp. Oil should not be used instead of a soap solution for locating Freon-12 leaks, because the oil will absorb the refrigerant and hold it for the possible confusion of following tests with the torch.

Leakage of Methyl Chloride.—Systems using methyl chloride are tested for leaks with a soap solution, exactly as just described for tests on a system containing Freon-12. The low-side pressure first is raised to 10 or 15 pounds per square inch, the entire system is tested, then the pressure is brought up to 35 or 40 pounds and the tests are repeated. Oil instead of a soap solution should not be used for locating methyl chloride leaks.

Leakage of Sulphur Dioxide.—To test for leaks in a system using sulphur dioxide the low side pressure first is raised to five or ten pounds per square inch, all joints are tested, then the low-side pressure is raised to 25 or 30 pounds and the tests are repeated.

Sulphur dioxide leaks are located by applying to the suspected points 28 per cent aqua ammonia, which is an ammonia solution much stronger than ordinary household ammonia. The ammonia is applied all the way around each joint. If sulphur dioxide is escaping it combines with the ammonia to form ammonium sulphite which appears as a white fog, or like a white smoke. Application is made with a small brush or with a cloth swab held

on the end of a wire handle. The ammonia solution should not be allowed to touch brightly finished metal parts, since it tends to discolor or corrode them. The fumes may be easier to see if the beam from a flash lamp is played on the joint being tested.

Leak Repairs.—The discovery of one leak does not mean that there are no others, so every possible point of leakage should be carefully tested. Every leak must be closed before the apparatus is continued in operation. This may require making new flared or soldered joints for tubing, it may require new fittings where the threads have been damaged, it may require new gaskets in joints, new packings in valves, or whatever other corrective measures are required for the part at fault.

Threaded joints may be made tight by applying to the male threads a paste made from litharge and glycerine mixed to about the consistency of thin library paste. This combination sets hard in a short time. The remainder of whatever quantity has been mixed may as well be thrown away, for it hardens and becomes useless.

Where tubing connections are subjected to temperatures below 32° F. the spaces between the tubing and the nut may be filled with any non-oxidizing grease to keep out water. Water from condensation may get into these spaces and collapse the tube upon freezing.

CHAPTER 10

ADDING AND REMOVING REFRIGERANT

With a system in which there is too little refrigerant the required low temperatures will be obtained only with excessive running time of the compressor, if at all. Low-side and high-side pressures will be well below normal while the compressor is operating. The evaporator will tend to lose its coating of frost. When you listen attentively at an expansion valve or at a low-side float valve it may be possible to hear an intermittent or steady hissing caused by refrigerant vapor passing through the valve along with liquid. This is a sound which, after a little experience, is readily distinguished from that of liquid alone. The hissing will be more noticeable if an expansion valve is momentarily opened beyond its usual setting.

Some systems have a sight glass in the liquid line. Through this glass may be seen the steady flow of liquid refrigerant with a normal charge, or the bubbles of vapor which indicate lack of refrigerant. In a correctly charged system the liquid level in a condenser-receiver remains just below the bottom tubes, but always covers the liquid outlet to prevent hot gas from going to the evaporator. A separate receiver may normally be 70 to 90 per cent filled with liquid. Gage glasses are fitted to some receivers.

If a system having a combined condenser-receiver contains an excess of refrigerant too much of the tubing will contain condensed liquid and too little will contain condensing vapor. To cause enough condensation with the reduced heat-dissipating surface the temperature difference between refrig-

erant and air or water must increase. This higher internal temperature causes higher condensing pressure, so abnormally high condensing pressure may indicate an excess of refrigerant. With a separate receiver any such excess as ordinarily may exist will simply remain in the receiver and will have little effect on operation of the system.

Adding Refrigerant.—Refrigerant added to a system is taken from a steel cylinder, sometimes called a drum, fitted with a hand-operated valve at one end. Cylinder sizes are specified according to the weight of refrigerant they are designed to hold when filled to normal capacity. Common sizes are 3, 5, 10, 25, 50 and 145 pounds of a specified refrigerant. Since weights per pound differ with various refrigerants the cylinder dimensions in inches depend on the kind of refrigerant. Cylinders ordinarily are marked with their *tare weight*, which is the weight of the cylinder when empty. Weighing a cylinder containing refrigerant, then subtracting the tare weight, gives the weight of contained refrigerant.

Refrigerant is added to a system while the compound gage and pressure gage are attached respectively to the low side and high side. After adding a small quantity of refrigerant the charging cylinder is shut off and the apparatus operated in a normal manner for possibly 15 or 20 minutes. If the pressures become normal, considering the room temperature when working with an air-cooled condenser, if hissing sounds no longer are heard from refrigerant valves, and if the evaporator frosts in a normal manner, the charge may be considered sufficient. Otherwise a little more refrigerant is added and again the operation of the system is observed.

In systems equipped with expansion valves and

separate receivers the amount of refrigerant charge is not very critical, so after the indications of insufficient charge disappear some additional refrigerant is added to provide a reserve. The extra amount depends on the size of the parts and capacity of the system, being anywhere from a fraction of a pound to several pounds. The same procedure is followed with low-side float systems, adding a little refrigerant to raise the level in the header.

Systems equipped with high-side floats and those with capillary tubes must be given just the correct charge, with possibly an ounce or two added to make up for that which may be lost during a following purging operation. In these systems only a little refrigerant should be added at one time, or only enough to cause a moderate rise of high-side pressure, and then the operating performance should be observed before adding any more refrigerant.

Refrigerant may be added in the form of vapor to the low side of the refrigeration system or it may be added in the form of liquid to the high side. It takes longer to add a given quantity of refrigerant as vapor to the low side than as liquid to the high side. Low side charging is used for many small domestic refrigerators, while high side charging is more often used with larger commercial systems or, as with some hermetic types, where the high side method is more easily applied.

Low-side Charging with Vapor.—The procedure for adding refrigerant through the low side of the system is as follows. Connections are shown by Fig. 106.

1. Connect a pressure gage to the discharge service valve or elsewhere on the high side.
2. See that the receiver service valve or other outlet to the liquid line is open.
3. With the suction service valve fully open re-

move the gage port, attach a tee fitting, mount a compound gage on one leg of the tee, and leave the other leg for connection to the refrigerant cylinder.

Use a tubing connection long enough to be flexible, usually with a loop of one or more turns. This allows movement of the cylinder, as when weighing

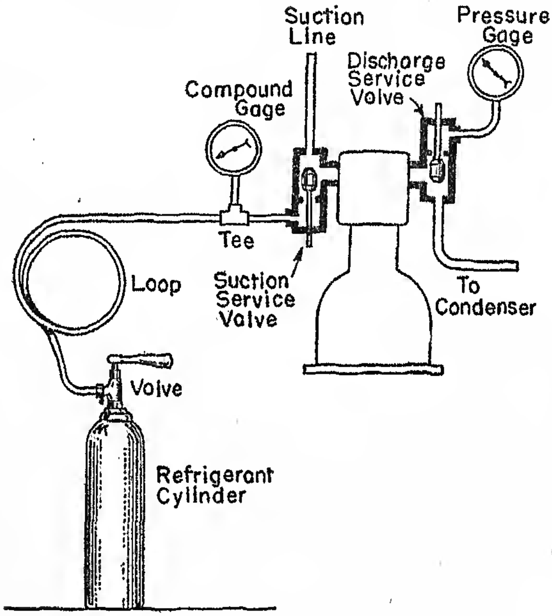

Fig. 106.—Low-side Charging with Vapor.

it on a scale, without loosening any joints. The cylinder should be upright, with its valve at the top, so that only vapor will issue from it.

4. Tighten the tubing connection at the cylinder, leave the connections loose at the compound gage and suction service valve, slightly open the cylinder valve for a few moments to purge the tubing line, and then tighten the connections.

5. Close the suction service valve, shutting off the suction line.

6. Start the compressor and open the refrigerant cylinder valve. Adjust this valve, and re-adjust it as necessary, to maintain a low positive pressure (above atmospheric) on the compound gage. This pressure will be produced by the evaporation of the relatively warm refrigerant in the refrigerant cylinder.

Another method is to start the compressor and gradually close the suction service valve until the compound gage shows about two pounds pressure, then open the valve on the refrigerant cylinder and re-adjust the suction service valve as may be necessary to maintain the pressure on the compound gage.

7. Continue the charging until it is desired to make a test of performance. To test the performance, close the cylinder valve, place the suction service valve in a partially open position (leaving an opening to the compound gage) and observe the operating pressures at the evaporator.

8. Evaporation of refrigerant from the cylinder will lower the temperature in the cylinder, and this lowered temperature will diminish the rate of evaporation. To hasten the process the refrigerant cylinder may be immersed in a pail of warm water. The cylinder never should be heated to more than 120° to 125°, chiefly because there is a fusible safety plug which will melt and open at around 150° to 160°, and which may soften at lower temperatures.

9. When the charging is finished, close the cylinder valve, place the suction service valve in its normal operating position and pump down the system or balance the pressure to just above zero on the compound gage. Then remove the charging connections, plug the gage port, and cap the service valve.

High-side Charging with Liquid.—The connections for one method of high-side charging are shown by Fig. 107. The procedure is as follows:

1. The compressor should have remained idle for long enough to let high-side pressure drop to a value corresponding to room temperature.

2. A compound gage is connected to the suction service valve or to some other point on the low side.

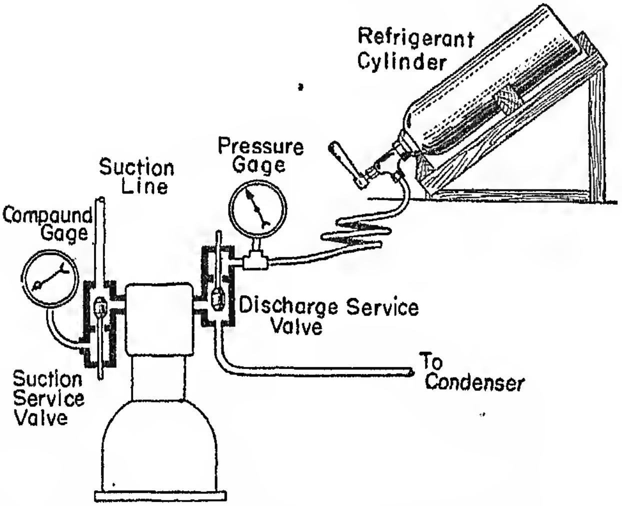

Fig. 107.—High-side Charging with Liquid.

To the discharge service valve is connected a tee fitting. A pressure gage is connected to one leg of the tee. The other leg is connected to the refrigerant cylinder. The purpose of the gages is to allow checking performance of the system after some refrigerant has been added, thus determining whether still more refrigerant is needed.

3. A support for the refrigerant cylinder should be arranged to keep the cylinder inclined about as

shown by Fig. 107, with the outlet valve downward so that only liquid will flow out of the cylinder. The cylinder should not be placed vertically with its valve at the bottom, for this would allow any dirt in the cylinder to pass into the refrigeration system. With an inclination such as shown the dirt will remain inside the cylinder, at the lowest point.

4. Refrigerant will flow from the cylinder because of gravity due to its elevation and because pressure in the cylinder is greater than in the high side of the system. To have greater pressure in the cylinder its temperature must be above that of the condenser and receiver. Cylinder pressure may be raised by first immersing it in water whose temperature is not above 120° or 125°, or by applying cloths wet with hot water.

5. With the cylinder connected and the discharge service valve still fully open, the connection at the cylinder is tightened while those at the service valve and gage are left loose while the cylinder valve is opened momentarily to purge the charging tubing. Then all charging connections are tightened.

6. Turn the discharge service valve to its mid-position. Then open the cylinder valve a little ways. A faint hissing sound may be heard at the cylinder valve so long as refrigerant is flowing. No sound at the valve indicates that the pressures in the cylinder and high side have become equal or that the cylinder is empty. High-side pressure may be measured by closing the cylinder valve. Pressure from the cylinder may be measured by fully opening the discharge service valve and opening the cylinder valve.

7. Performance of the system may be checked by closing the cylinder valve, placing both service valves in normal operating positions (fully open), and starting the compressor.

8. To remove the cylinder close the cylinder

valve, wait a few minutes for the charging line to empty of liquid, fully open the discharge service valve, and disconnect the charging line and pressure gage.

Adding a Complete Charge.—When refrigeration equipment has been newly assembled or has had extensive repairs, and contains no refrigerant, the charging operation is in general as follows:

1. In accordance with procedures previously outlined, enough refrigerant is added through either the low side or high side to bring the internal pressure to about 10 pounds gage. The system then is completely tested for leaks, more refrigerant is added to produce a pressure of 25 to 40 pounds, the leak tests are repeated and all leaks are eliminated. Leak tests sometimes are made by admitting compressed air or carbon dioxide instead of using the regular refrigerant.

2. The next step is to evacuate and dehydrate the system. Preparatory to this work enough oil is added to bring the level in the compressor to the normal operating point. With force-feed oiling the compressor should be operated to make sure that the oil pump is working.

3. The system is evacuated with the valves placed as shown by Fig. 108. Evacuation also dehydrates, since it removes most of the moisture-bearing air. A compound gage is connected to the suction service valve, and the valve is turned to mid-position so that the gage will indicate low-side pressure. The discharge service valve is closed and the gage port is opened and left open, so that air pumped out by the compressor may be exhausted through the gage port. The receiver valve or whatever connection leads from the condenser-receiver to the liquid line is opened.

4. Operate the compressor for a minute or two

at a time for three or four times to slowly reduce the internal pressure. Then run the compressor continuously until the greatest possible vacuum is obtained. Depending on the type of construction and the compressor efficiency the maximum vacuum may be from 20 to more than 28 inches on the gage. During this evacuation all parts of the system

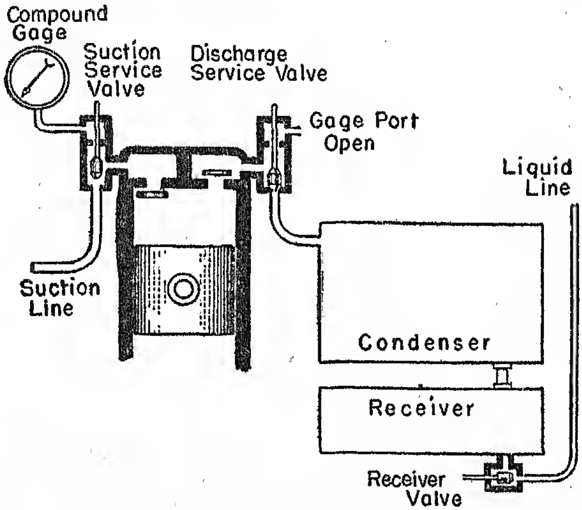

Fig. 108.—Valves Arranged for Evacuating Before Adding a Complete Charge of Refrigerant.

should be kept at the highest practicable temperature. Heat may be applied with a torch to assist in driving out moisture, but great care must be used not to overheat parts such as soldered joints.

5. Since the maximum vacuum obtainable with the compressor alone is not enough to do a really first class job of evacuating and dehydrating, it is desirable to now connect an external vacuum pump to the gage port of the discharge valve gage port and reduce the vacuum to about 0.2 inch of mercury

absolute or to around 28.8 inches gage. This will take several hours.

6. The system now is charged with refrigerant in the regular way, through either the low side or high side. The charge should consist of the weight of refrigerant recommended by the manufacturer. This weight of refrigerant is placed in the refrigerant cylinder to begin with, and all of it is admitted into the refrigeration system.

Purging may be required once or more between the beginning and end of a charging operation in case the high side pressure tends to run excessively high. After a complete charge, and preferably after a partial charge, the system should be dehydrated. Dehydration is made easier if the dehydrator is connected into the liquid line before the charging operation, and left there for some time afterward.

Removing Excess Refrigerant.—If a system contains too much refrigerant a small quantity may be released by following the procedure for purging air, but continuing until refrigerant as well as air is purged. A pressure gage should be connected to the high side so that pressure may be observed as it is reduced to normal.

If the removed refrigerant is to be saved instead of being discharged into the air or a lye solution the procedure is as follows:

1. The refrigerant is discharged into an empty cylinder placed upright, with its valve at the top, set in a pail or other container with cracked ice. The low temperature in the cylinder causes condensation of refrigerant vapor in it as the vapor comes from the refrigeration system which is maintained at a relatively high temperature by keeping cabinet doors open and, with domestic units, placing warm water in ice cube trays.

2. The empty cylinder may be connected to a

purge valve if one is available, or to the gage port of the discharge service valve. With the latter connection the valves are arranged as shown by Fig. 108. In any case, a valve should be closed at a point beyond that from which refrigerant is discharged, so that the compressor may draw refrigerant out of the system beyond the point shut off.

3. A compound gage should be fitted to the suction service valve and this valve turned to its mid-position so that low-side pressures or vacuums may be read.

4. With the cylinder valve open and with the connections opened from the refrigerant system to the cylinder, the compressor is operated for a short time to pump out some refrigerant. Then the cylinder valve is closed, the system valves placed in normal running positions, and performance of the apparatus is observed to note whether it indicates no excess of refrigerant. More refrigerant is drawn out if necessary. The cylinder may be weighed before and during the discharge if it is desired to know just how much refrigerant is removed.

Removing All Refrigerant.—The entire charge of refrigerant may be removed into an empty cylinder by following, in general, the method outlined for removing excess refrigerant. The empty cylinder must positively be of sufficient capacity to hold the entire charge of the particular refrigerant being handled, or else additional empty cylinders must be at hand.

A compound gage is attached to the low side. It is advisable to attach a pressure gage to the connection leading to the cylinder so that excessive high-side pressure may be noted and the compressor stopped until the pressure drops.

With all connections completed and valves in the discharge positions the compressor is run until all

parts of the refrigeration apparatus are warm and until the compound gage shows a vacuum of 20 inches or more. If the cylinder is not large enough to take the entire charge, the cylinder must be kept on a scale and when its weight has increased by its capacity in pounds of refrigerant, this cylinder

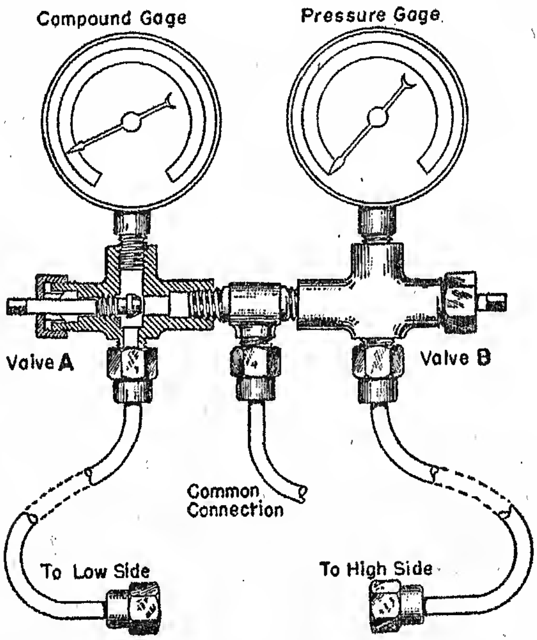

Fig. 109.—The Parts of a Combination Gage Manifold.

must be removed and another substituted. In order to permit evacuation with the evaporator at high temperature it will be necessary to open an expansion valve if such a valve is used for refrigerant feed.

Combination Gage Manifold.—Fig. 109 shows an assembly of connections which allows convenient

measurements of pressures and vacuums and saves time in carrying out many service operations. The tubing connections for the low side and high side are run to the suction service valve and discharge service valve on the compressor or to other attachment points.

At the left-hand side of Fig. 110 are shown the valve positions when using the combination test set for measuring low-side vacuums or pressures and

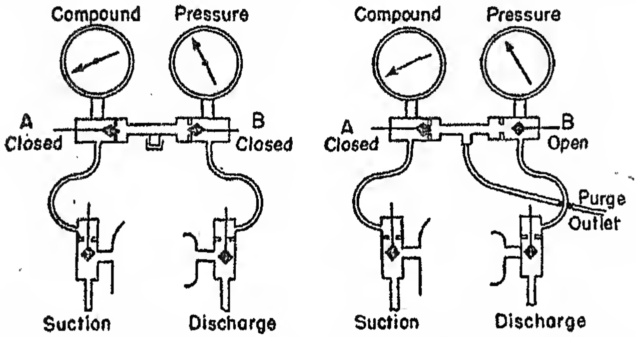

Fig. 110.—Using the Combination Manifold for Pressure Measurements (left) and for Purging or for Removing Refrigerant (right).

high-side pressures. Both test set valves are closed and both service valves are in their mid-positions. This connects the low side to the compound gage, connects the high side to the pressure gage, and isolates the two gages from each other.

At the right-hand side of Fig. 110 are shown valve positions for purging air or for removing some of the refrigerant. Valve *A* is closed, valve *B* is open, and both service valves are in their mid-positions. The purge outlet tubing is connected to the common connection on the test set and is run outdoors, to a lye solution, or to wherever the refrigerant and air are to be discharged.

Fig. 111 shows connections and valve positions for adding refrigerant to the system. Charging with refrigerant vapor through the low side is shown at the left, and with refrigerant liquid through the high side at the right. The paths followed by entering refrigerant are indicated by arrows. The general procedures for charging are the same as previously described, the only difference being that all changes of connections and all operating tests are

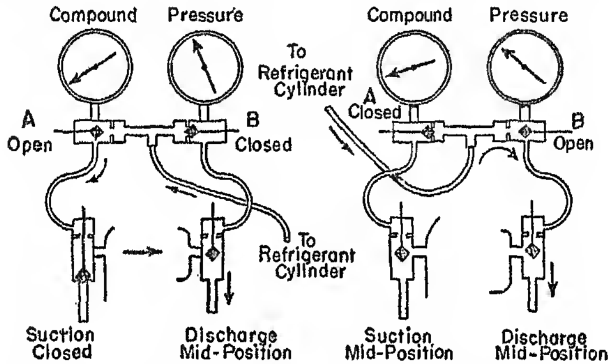

Fig. 111.—Using the Combination Manifold for Adding Refrigerant as Vapor (left) and as Liquid (right).

easily made by manipulating the valves on the test set and on the refrigeration apparatus.

Filling a Service Cylinder.—Small refrigerant cylinders used for charging individual systems or for adding refrigerant usually are called *service cylinders*. A method of filling a service cylinder from a large supply cylinder is shown by Fig. 112. The procedure is as follows:

1. The service cylinder should be evacuated and dehydrated before filling. This usually is done by connecting it to the suction side of a shop pump or compressor used for evacuating. The cylinder is

pumped down to the greatest possible vacuum while being heated to not over 125° in hot water, then its valve is closed.

2. The two cylinders are connected together with flexible looped copper tubing to allow weighing without any drag from the connection.

3. The supply cylinder is inclined, with its valve downward, so that charging is done with liquid refrigerant.

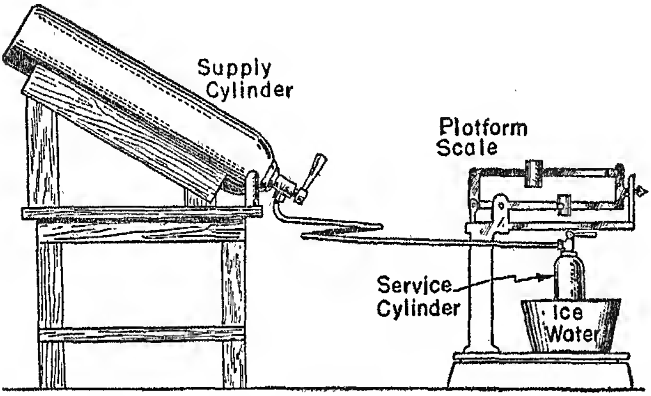

Fig. 112.—Filling a Service Cylinder from a Supply Cylinder.

4. The service cylinder is placed in a container filled with cracked ice. The supply cylinder may be warmed with hot water or hot cloths to not over 125°. Pressure in the service cylinder thus is kept below that in the supply cylinder.

5. Weigh the empty service cylinder with its ice bath and container on a platform scale. To this weight add the number of pounds of refrigerant to be placed in the service cylinder and set the scale for the sum of these weights. When the scale beam rises it indicates that the service cylinder has been

filled. The cylinder must not be given more than its rated capacity in pounds, although any smaller quantity may be put in. Instead of weighing the service cylinder the large supply cylinder may be weighed, the weight of desired charge subtracted, and the scale set for the difference.

6. Keep the service cylinder valve closed, leave the connection loose at the service cylinder, and momentarily open the supply cylinder valve to purge air from the connecting tubing. Then tighten the connection, open the service cylinder valve, and open the charging cylinder valve until the desired weight of refrigerant passes into the service cylinder.

7. Close the supply cylinder valve, wait a few minutes for the charging line to empty, then close the service cylinder valve and disconnect this cylinder. The charging connections may be left on the supply cylinder.

If the service cylinder cannot first be evacuated with a compressor used as a vacuum pump or with some suitable vacuum pump, admit a little liquid refrigerant to this cylinder, close the cylinder valve, temporarily remove the charging connection, and carefully crack the cylinder valve to allow evaporation of the refrigerant to purge air from the cylinder. This method should be used only in emergencies.

Care of Refrigerant Cylinders.—Cylinders must not be subjected to excessive shock; they must not be dropped, allowed to strike one another violently, or stored where they may be struck hard by passing objects. Except when a cylinder is being used its valve and threads should be protected with a cap. Do not attempt attaching a fitting whose threads do not match those of the cylinder. Valves should be operated only with wrenches that fit their stems

snugly. Do not subject cylinders to direct sunshine nor to surrounding temperatures over 125°. When a cylinder is emptied close its valve immediately to prevent entrance of air and moisture.

Discharge refrigerant from an operating system only into a service drum kept for this purpose, since dirt may come out with the refrigerant. Refrigerant from a service drum in which there may be dirt should be pumped out of that drum as a vapor, with the valve at the top, and run through a dehydrator as it is fed into another clean cylinder. The cylinder being emptied may be heated and the other one cooled to assist the transfer. The dirty cylinder is cleaned by removing its valve and flushing with carbon tetrachloride, then heated to not over 125° while being evacuated with a pump. If the cylinder is dried in an oven the fusible plug should first be removed, since it will be melted by the oven heat which usually runs around 250°.

CHAPTER 11

ADDING AND REMOVING OIL

Lubricating Oils.—Oil for refrigeration compressors may be described by giving the viscosity, pour point, flash point, fire point, specific gravity and other characteristics. There are so many variables that it is advisable to use the kind of oil recommended by the manufacturer of the equipment or by a reliable supply house, without worrying about the specifications.

Viscosity usually is specified as the number of seconds required for a given volume of oil to pass through a certain small opening when the oil is at a specified temperature. Refrigeration oils commonly have viscosities between 75 and 300. The higher viscosity numbers indicate an oil that takes longer to flow, or an oil which is called "heavy" to distinguish it from "light" oils which flow more rapidly. The pour point is a temperature below which the oil no longer may be poured. The flash point is a temperature at which oil vapor ignites with a puff when a flame is held above its surface, but at which the oil does not continue to burn. The fire point is a temperature at which the oil continues to burn. The specific gravity is a measure of the weight of a given volume of oil in comparison with the weight of an equal volume of water.

Oil absorbs or takes up an appreciable amount of Freon-12 or of methyl chloride, but very little sulphur dioxide. Freon-12 and methyl chloride thus tend to make the oil thinner, so oils for use with these refrigerants must be heavier or of higher viscosity to begin with than those used with sulphur dioxide. Systems having expansion valves and dry

evaporators will use heavier oils than those otherwise similar except for being of the flooded type. Large compressors operating at relatively high temperatures and pressures require heavier oils than small machines operating at lower temperatures. To effectively seal spaces around rotors and blades in rotary compressors requires heavier oils than used for reciprocating piston compressors.

A refrigerant that absorbs oil will take up more oil when pressures are high and temperatures low than at lower pressures and higher temperatures. When a compressor stops and remains idle for a time the temperature of crankcase oil drops and the pressure inside the crankcase rises, so under these conditions the oil absorbs more refrigerant and there is an increase of total volume of the mixture. When the compressor again is started the crankcase pressure drops and temperature of the oil tends to rise because of friction in the mechanical parts. Then the refrigerant is released from the oil, usually with sufficient rapidity to cause foaming. The volume of the oil-refrigerant mixture now decreases and particles of oil are carried with refrigerant vapor throughout the entire system.

A certain amount of oil circulation is desirable because the oil helps lubricate moving parts of refrigerant valves. However, excessively rapid release of oil may allow "slugs" of oil to get above the piston, cause pounding of the machine, and often seriously damage the suction and discharge valves. It is possible also for so much oil to leave the crankcase of the compressor as to leave the bearings with so little lubrication that they are damaged.

All refrigeration oils are hygroscopic, meaning that they readily absorb moisture. Oils come in small sealed cans, thoroughly dehydrated, and must be kept in a clean, dry place after the cans are

opened. It is still better, when all oil from a can is not immediately put into a compressor, to use the remainder for some other lubricating work rather than putting it into refrigeration apparatus. Freedom from moisture is especially important with oils to be used with sulphur dioxide equipment.

Checking the Oil Level.—In the walls of many compressor crankcases are glass bull's-eyes or sights through which the level of oil may be observed with the help of a flash light. If the oil level is within the range of the glass it will show as a distinct line. The correct level usually is from one-fourth to three-fourths of the way up the glass. If no oil line is visible, but if the glass appears dark and if an occasional bubble may be seen rising, the oil level is above the top of the glass. If the glass appears uniformly light in shade, the oil level is below the bottom of the glass.

With many of the smaller compressors there is no oil sight glass, but there may be a removable plug part way up on one side of the crankcase. This plug may be taken out to allow insertion of a rod which, when withdrawn, shows the oil level by the height to which the rod is covered with oil. Fig. 113 shows the location of a bull's-eye, also a gage rod attached to a plug, both on the same compressor although ordinarily only one or the other of these level indicators would be used. When a rod is attached to the plug it is removed, wiped clean, reinserted and then lifted out again to note the oil level.

The oil level should be checked after a normal period of operation and when the compressor has just been stopped by the cycling control or is almost ready to be so stopped. It is at this time that there is the least refrigerant in the oil, and an oil level check will indicate true conditions. After a long idle

period there will be the maximum quantity of refrigerant in the oil and a check indicates little. The level may be high, and yet there actually may be too little oil because of so much refrigerant in the mixture. Should the level be low after a long period

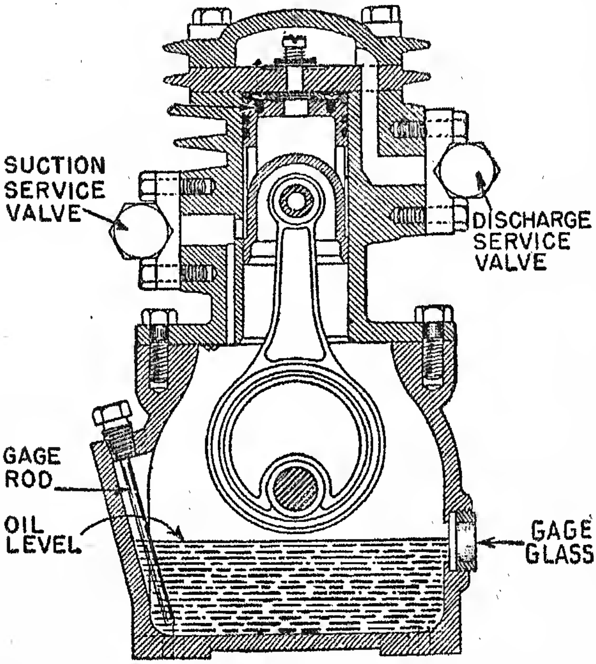

Fig. 113.—Oil Level Gage Rod and Sight Glass or Bull's-eye in Compressor Crankcase.

of idleness it indicates a serious lack of oil, because even the refrigerant and oil together fail to raise the level.

To check the oil level proceed as follows:

1. Connect a compound gage to the low side, then start the compressor.

2. Slowly close the suction service valve until the low-side pressure becomes zero or just above zero.

3. Stop the compressor and quickly close the suction service valve all the way, thus shutting off the suction line.

4. Close the discharge service valve to shut off the discharge line.

5. Read the oil level on the sight glass or with a gage rod.

6. Replace and tighten the gage plug (if the oil is thus checked) and return the service valves to their normal operating positions.

Adding Oil.—Oil sometimes is added through the opening left by removing an oil gage plug. The success of this method depends on the fact that refrigerant vapor in the crankcase is heavier than air, so naturally keeps the crankcase full of vapor while some of the vapor is displaced by the added oil. By working slowly and carefully, air may be prevented from getting into the crankcase through the plug opening.

1. Attach a compound gage to the low side, run the compressor until the crankcase pressure is about one pound, then stop the compressor.

2. Close the discharge service valve to shut off the discharge line, also the suction service valve to shut off the suction line.

3. Slowly remove the oil gage or oil filler plug.

4. Add the required quantity of oil, slowly, through a clean, dry funnel.

5. Replace and tighten the plug.

6. Place the service valves in their normal position.

Oil may be added through the suction service valve as shown by Fig. 114. The procedure is as follows:

1. Prepare a clean, dry glass bottle or other oil container which will hold the quantity of oil to be added. The container may be graduated in ounces. Fill the container with somewhat more than the quantity of oil to be added.

2. With the suction service valve fully open attach to the gage port a tee fitting, a compound gage, a hand-operated shutoff valve, and a length of tubing which will reach almost but not quite to the bottom of the oil container, all as shown by Fig. 114.

3. Let the compressor stand idle for a few minutes

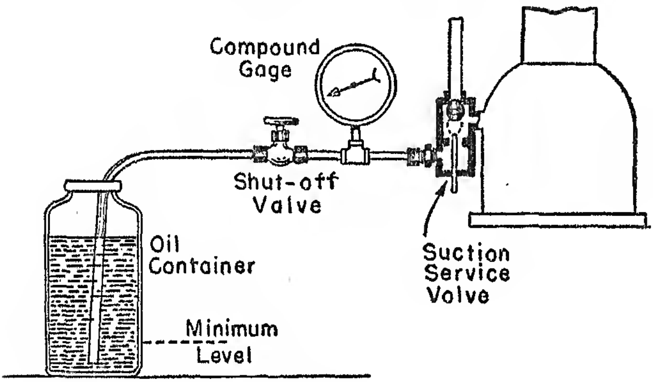

Fig. 114.—Adding Oil through the Suction Service Valve.

to build up a small low-side pressure, then open the shutoff valve and crack the suction service valve to purge air from the tubing line. The air will be forced out through the oil.

4. Close the shutoff valve and place the suction service valve in mid-position.

5. Start the compressor and slowly close the suction service valve to lower the pressure indicated by the compound gage. Too rapid closing of this valve may cause enough oil to be drawn above the piston to damage the compressor valves.

6. With the suction service valve fully closed, continue running the compressor to obtain a good vacuum, at least 15 inches or more. Then stop the compressor.

7. Open the shutoff valve. The vacuum in the compressor crankcase will allow oil to be forced into the compressor by the excess of atmospheric pressure on the oil container. Close the shutoff valve when the desired quantity of oil has been forced into the compressor, but never allow the oil level in the container to drop so far that there is less than a half inch of oil above the lower end of the tube. A lower oil level would permit air to be forced through the tubing into the compressor crankcase.

8. If oil ceases to flow into the compressor before the desired quantity has been added, close the shutoff valve and again pump a vacuum in the crankcase. Then open the shutoff valve to admit more oil. This procedure may be repeated if necessary.

Oil may be added through the suction service valve by using the combination gage set as shown by Fig. 115.

1. A tube is run from the common connection of the test set to near the bottom of the oil container.

2. Valves *A* and *B* are closed. Both service valves are set at their mid-positions.

3. After the compressor has remained idle for long enough to build up some low-side pressure, purge the oil tubing through the oil in the container by alternately opening and closing valves *A* and *B*.

4. With valves *A* and *B* closed the compressor is started, then the suction service valve is slowly closed to reduce the low-side pressure and, after this valve is fully closed, the compressor is run to

obtain a good vacuum. Then the compressor is stopped. The compressor must not be operated with valve *A* open.

5. Valve *A* now is opened to allow oil to be forced from the container through valve *A* and the suction service valve into the evacuated crankcase. Valve *A* is closed when the desired quantity of oil has been added.

6. If not enough oil is forced into the compressor, close valve *A* and again run the compressor to

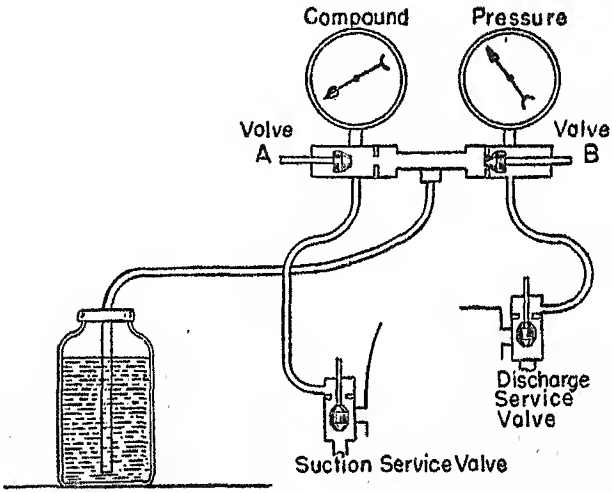

Fig. 115.—Using the Combination Manifold for Adding Oil.

obtain a good vacuum in the crankcase. Then valve *A* may be opened to admit more oil.

Instead of drawing oil from a transparent container, in which the lowering of the level may be seen, oil may be taken directly from a can or other non-transparent container. The can must be set on a scale and kept there as oil is drawn from it. From

the weight of the full can subtract the weight of oil to be added to the compressor and set the scale at this lesser weight. Stop the oil charging when the scale indicates that the lesser weight has been reached. Refrigeration oils weigh from about 14.7 to 15.5 ounces per pint liquid, or weigh from about 0.92 to 0.97 ounces per fluid ounce.

Complete Oil Charges.—The correct normal quantities of oil for various compressors are specified by their manufacturers and must be adhered to when adding a complete oil charge. In domestic and small commercial systems the oil charge varies from six or seven ounces to two or three quarts. When there is doubt as to whether oil has been carelessly added to or withdrawn from a small system it is sometimes the practice to drain out all the oil and put in a known correct quantity.

When refrigeration equipment has been newly assembled or extensively overhauled the normal oil charge is added before evacuation, dehydration, and charging with refrigerant. A newly assembled compressor must not be run under power without some oil in its crankcase, and after oil is added the compressor should be rotated for a few revolutions by hand to distribute the oil before power is applied. Repaired compressors sometimes are "broken in" with lighter oil or oil of lower viscosity than the regular kind. After the compressor has been driven for some time, without connection to the remainder of the equipment, the light oil is discarded, the crankcase is flushed with more of the same light oil, and then the regular grade of oil is put in.

A system freshly charged with refrigerant should be watched carefully for the first few hours of operation, because oil carried into other parts of the apparatus may make the level too low in the compressor. Oil usually must be added once or

more to bring the level to the correct operating point. Although some refrigerant is absorbed by fresh oil, tending to raise the level, this effect is more than offset by oil absorbed into the refrigerant and distributed through the apparatus.

Removing Oil.—Oil should not be removed from a refrigeration system unless there is good reason for thinking that an excess has been added. An apparently high oil level may be due to refrigerant mixed with the oil after a long shut down. Oil should be completely drained and replaced with fresh after long periods of operation. This may be several years with domestic systems or only months with commercial systems. A sample of oil may be drawn into a small glass bottle, allowed to settle, then examined for sediment or dirt—the presence of which would call for complete replacement. Oil that has lost its "oiliness" or ability to cling to surfaces should be replaced.

Oil is removed from a compressor as follows:

1. Attach a compound gage to the low side.
2. Start the compressor and gradually close the suction service valve until the pressure (in the crankcase) drops to about one pound.
3. Close both service valves, then stop the compressor.
4. Oil now may be drained from any plug or valve below the oil level in the crankcase. If only a little oil is to be drained, open a valve only a little way or simply loosen but do not remove a screw plug so that oil seeps out around the threads and so that the plug may be tightened without delay when enough oil has been drained.
5. Tighten the plug or close the valve, then open the suction service valve while removing the gage and closing the gage port. Leave both service valves in their normally open positions.

CHAPTER 12

COMPRESSOR TESTS AND SERVICE

Among the more common troubles with compressors are leaks at the suction or discharge valves, at gaskets, or past the piston or piston rings. Such faults may be indicated by a sudden or gradual decrease of refrigerating ability, by failure to produce or maintain necessary low-side pressures or vacuums, and by continuous running or running too long during each cycle.

Testing for Compressor Leaks.—To test a compressor for leaks at valves, pistons or gaskets proceed as follows:

1. Connect a compound gage to the suction service valve and a pressure gage to the discharge service valve. See Fig. 116 at *A*.

2. Start the compressor and partially close the suction service valve, adjusting this valve so that the vacuum is reduced to 20 or 25 inches in not less than 10 minutes. The slow reduction of low-side pressure prevents too rapid separation of refrigerant from the crankcase oil and prevents getting an excess of oil onto the valves—which might make them temporarily free of leaks. If the vacuum cannot be made more than 10 or 15 inches, or if it takes a very long time to get the vacuum down to 20 inches or more, the indications are that the suction valve or valves are leaky.

3. Stop the compressor, open the suction service valve wide, and wait for zero low side pressure to build up. Opening the cabinet doors or warming the evaporator will hasten this step.

4. Again start the compressor. Close the suction service valve, and as soon as maximum vacuum is

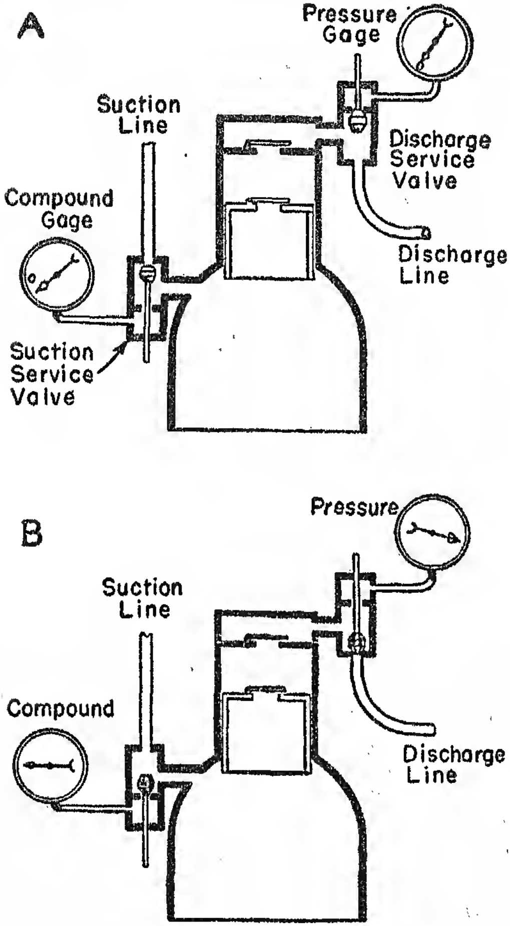

Fig. 116.—Initial Valve Positions When Testing for Compressor Leaks and Changed Position of Valves During Leak Tests.

obtained stop the compressor. The maximum vacuum now should be obtained in a half minute or less.

5. The vacuum should remain practically without

change for as much as five minutes. If the vacuum does not hold it indicates a leaky discharge valve and also a leaky suction valve or leaks past the piston or piston rings. This test for maintaining a vacuum should not be made until after the preliminary pull-down (step 2), for otherwise there may be so much refrigerant released from crankcase oil as to raise the gage pressure with the suction service valve closed.

6. Open the suction service valve. Wait for the vacuum to decrease. Then close the discharge service valve as in Fig. 116 at *B*.

7. Start the compressor, but keep your hand on the switch or the cord plug and stop the compressor as soon as the pressure gage shows a pressure of about 125 pounds. This rise of pressure should require only a few revolutions of the compressor. If the pressure rises slowly, or fails to rise high enough, it indicates a leaky discharge valve, leaks past the piston or rings, or leaks at the compressor head gasket. The same faults are indicated should the pressure drop rapidly after the compressor has been stopped, and while the service valve still is closed. After observing the conditions open the discharge service valve to relieve the high pressure.

Compressor Valve Repairs.—A compressor should be opened for work on the valves only when tests have shown a decided probability of valve trouble. Other causes for faulty operation should be checked first. When the valves are exposed do not touch the sealing surfaces with your hands because of possible moisture and corrosion. Never do any filing, scraping or grinding at the valves, because these processes usually leave foreign particles. Valve leaks often are caused by small dirt particles between the sealing surfaces and should be removed before the surfaces are marred or scored.

Valve seats, as well as the valves, usually are damaged. The best practice is to replace both parts with new ones rather than attempting repairs. Removable seats may be lapped to make them smooth. In an emergency the discs or other moving parts may be lapped, but they are much better replaced with new parts. A new valve should not be used with an old or damaged seat unless the seat is placed in perfect condition. Removable raised seats may be lapped quite effectively on a flat lapping plate, while some recessed seats may be lapped fairly well by using a valve which fits into the recess. Many types of seats require special fixtures and tools for lapping. Valve springs and supports should be replaced with new parts if they show any signs of corrosion or other damage.

If a valve is found broken, every piece must be recovered and all must be accounted for. Otherwise the pieces may damage cylinders, pistons and bearings. Pieces may have gotten into the piston, the cylinder, the crankcase, and the suction and discharge ports.

Lapping Methods.—Valves, seats and other flat parts may be lapped on a perfectly smooth and flat surface plate as shown by Fig. 117. The plate is made of cast iron. A sheet of plate glass sometimes is used in an emergency.

A portion of the plate somewhat larger than the part to be lapped is covered with a thin layer of lapping compound. For the first step in removing roughness and score marks the paste may be of powdered pumice, powdered tripoli, or Bon Ami, mixed with compressor oil to make a paste thin enough so that it tends to spread and flatten by its own weight. After the surface of the part lapped has been made smooth and free of noticeable marks it is polished with a paste of lapping rouge, or of

powdered sulphur, mixed with oil. Prepared lapping compounds allow doing good work.

The part to be lapped is held lightly on the plate and in such manner as to insure even contact, then is moved around over the compound with a figure "8" motion, finally covering a large area of the plate to prevent uneven wear of the plate itself.

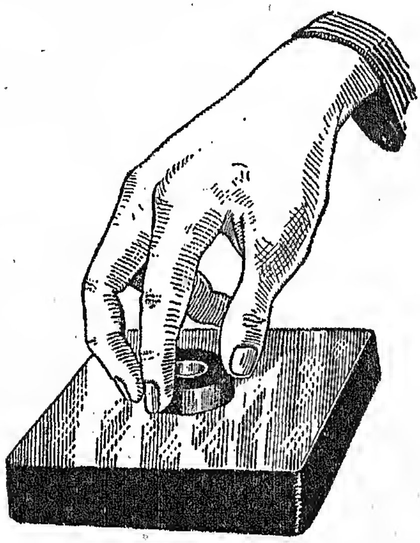

Fig. 117.—Lapping on a Surface Plate.

After a few minutes' lapping the part should be well cleaned with carbon tetrachloride, gasoline, or any cleaning compound, and examined. Unless all marks have been removed the lapping should be continued. When the part is smooth it should be polished with the second type of compound, then thoroughly washed.

After washing and drying the surface plate, rub the lapped part over it to check the flatness. A

correctly lapped part will show a bright polish over its entire surface. After the lapped part passes inspection it should be wiped with a clean cloth, lightly coated with oil, and, if not to be immediately installed, should be wrapped in waxed paper until needed.

Removing and Replacing the Valves.—To reach

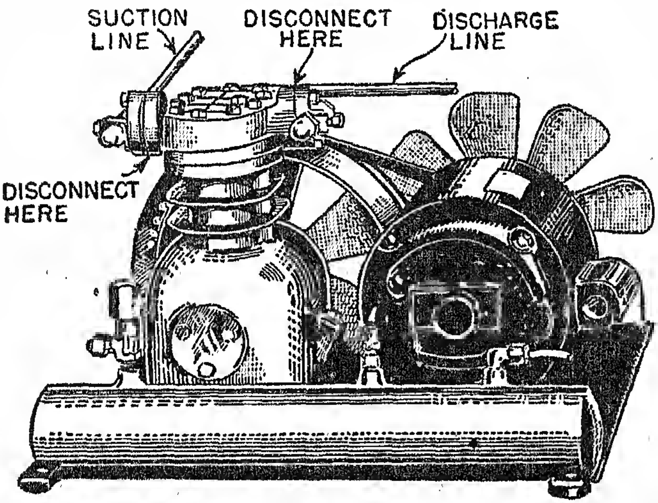

Fig. 118.—Service Valves and Their Tubing Lines Are Detached from the Compressor.

the compressor valves for inspection and repair proceed thus:

1. Close both the compressor service valves; suction and discharge.

2. Leave the suction line and discharge line connected to their respective valves and detach the valves from the compressor head or body. See Fig. 118.

3. Remove the bolts or screws that hold the compressor head. Lift off the head, being very careful

not to damage the head gasket. Remove valve assemblies from the valve plate, or remove the complete plate in order to get at any valves which are in the piston top. Use great care to observe and mark the original positions of every part removed so that it may be correctly replaced.

4. Replace or repair valve parts as may be required.

5. Clean and make smooth the surfaces on which gaskets rest. If the head gasket or gaskets are damaged, replace them with new ones of exactly the same material and thickness so that the cylinder space above the piston top will not be altered. Replace washers which have been flattened, also head bolts which show signs of having been stretched.

6. Turn down all the head bolts snugly, but not tightly. Then tighten those nearest the center before those toward the outside. Finally go over all the bolts to make them tight.

7. Clean the seating surfaces for the service valves on the compressor. It is best to use new gaskets here.

8. Fasten both service valves to the compressor.

9. Loosen the gage plug at the discharge service valve and then crack the suction service valve until refrigerant gas comes out of the loosened gage plug for purging.

10. Tighten the flare nut. Place both service valves in their normal open position. Test for leaks at all joints which have been disturbed.

Shaft Seal Service.—Tests with the halide torch for shaft seal leaks often give misleading results because the small quantity of oil normally leaking through the seal carries with it minute traces of refrigerant. Tests are best made with a soap solution after the low-side pressure is raised by warming the evaporator.

If the seal is to be removed because of squeaking or rasping noise, or because of only a slight leak, proceed as follows:

1. Pump down the system and balance the low-side pressure to zero or slightly above.

2. Remove the belt or other drive, and then the flywheel.

3. If the seal cover does not extend to the bottom of the crankcase the cover now may be removed, but if the entire end plate or a deep cover must be taken off it is necessary to first drain the oil. If there is a spring to take up end pressure (at the opposite end of the crankshaft), the spring cover should be loosened to relieve this pressure before taking out the seal.

4. Now remove the seal parts. Frequently they are attached to a flange which may be carefully pried out. Note and mark the positions of all parts so that they may be correctly replaced. The seal should be taken out before the crankshaft is removed. Otherwise there is danger that the end of the crankshaft will damage the seal. If the seal comes out hard, hold it while momentarily opening the suction service valve to build up crankcase pressure. Be careful not to drop any parts of the seal as they come out.

5. After necessary repairs are made, the contacting surfaces of the seal should be covered with oil before being replaced. A new gasket should be used for the cover plate.

If leakage is so bad as to indicate a broken seal the compressor should not be pumped down, for this will draw a great deal of air and moisture into the system. Instead, proceed as follows:

1. Close both the suction and discharge service valves.

2. Relieve the compressor internal pressure by opening the gage ports on both valves.

3. Drain the oil and leave the drain open so that pressure of gas released from the oil won't blow out the seal when it is uncovered.

4. Remove the flywheel and proceed from this point as in the preceding instructions.

With the seal parts removed, wash the sealing surfaces with gasoline or carbon tetrachloride and a soft brush and inspect them. Never touch these surfaces with your hands. Dirt on the surfaces may come away, or may require lapping to remove it. Surfaces which are scored, scratched, corroded or worn call for lapping or replacement. One part may be damaged and the other appear in good condition, but if either is replaced with a new part the other should be replaced at the same time unless it is the crankshaft itself—and oftentimes the shaft must be replaced. Slight damage to the shaft, when used as a sealing surface, may be removed by lapping. Any parts which are deeply pitted or badly worn should be replaced.

The sealing surfaces may not be running parallel with each other. Wash them thoroughly, allow them to dry without wiping, brush on a coat of Prussian blue, and rub the parts together. Unless all the blue comes off, the parts do not correctly match and they should be replaced.

If the bellows or diaphragm is cracked, or if there is defective soldering, this part should be replaced. To test the bellows set it upright on a sheet of rubber or similar material supported by a flat surface. Fill the bellows with cleaning liquid. Cover the top with another thin sheet of rubber and a flat board. Pressing lightly on the board will cause liquid to come out through any leaks.

The seal spring should be under some compres-

sion when in place. Pressure depends on the spring and on the number or thickness of spacing washers used. Manufacturers often issue instructions for checking spring pressure.

Lapping of Shaft Seals.—Methods of shaft seal construction are shown by Fig. 119. At *A* the collar of the shaft rotates against the stationary seal ring which is attached to the bellows, and the only sur-

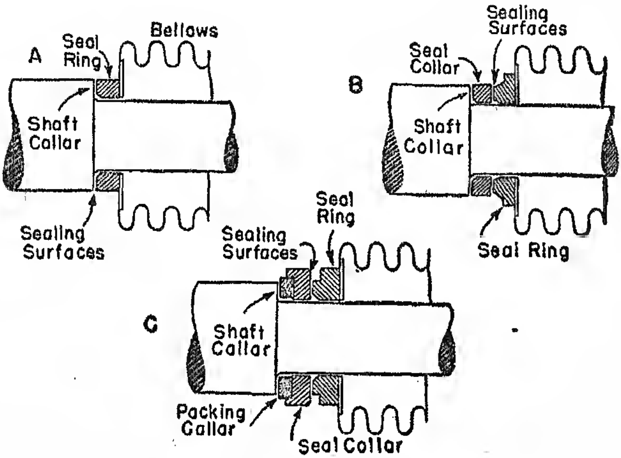

Fig. 119.—Shaft Seal Constructions, Showing the Surfaces Which May Require Lapping.

faces to be lapped are the sealing surfaces between shaft and ring. At *B* there is an extra seal collar between the shaft and the seal ring. Here there are two pairs of surfaces to be lapped; one pair between seal ring and seal collar, another between seal collar and shaft. At *C* a packing collar, often of molded synthetic rubber, is in direct contact with the shaft. Here the only surfaces to be lapped are between the seal ring and the seal collar.

Metal to metal contacting surfaces are lapped

together by using any of the lapping pastes mentioned for use with valves and valve seats; removing roughness (if present) with the coarser materials, and always finishing with a fine material such as rouge. Paste is spread evenly over one of the surfaces, the shaft collar or seal collar, then the ring is pressed lightly and evenly against the collar while the ring is repeatedly rotated through part of a turn in each direction. Rotation should be farther in one direction than the other, so that the ring gradually is turned around and around the collar.

Lapping compound should be used sparingly so that it won't get into the shaft bearing. Less and less compound should be used as the work proceeds. After the surfaces are smooth, and all compound has been washed off, the finishing touches are given with oil alone. Finally, the surfaces should be thoroughly cleaned, allowed to dry without wiping, then rubbed together as a final lapping operation. A final examination may be made with a good magnifying glass to make sure that there are no scratches or mars of any kind.

Sealing surfaces of removable rings or collars may be lapped smooth on a surface plate as shown by Fig. 120; using the same kinds of lapping compound and the same general procedure as for valves. A badly roughened crankshaft may be smoothed by using a discarded ring or collar for the lapping member which is rotated against the shaft while using the coarser grades of compound. After the shaft is smooth it should be lapped with the ring or collar with which it will be assembled and used. A part lapped separately, as in Fig. 120, should finally be rubbed on the part with which it will be used, to make certain that they match exactly. If necessary, the two parts should be lightly lapped together with rouge.

Removing a Compressor for Repairs.—Before a compressor is removed from a condensing unit or a refrigerator the refrigerant should be gotten out of the compressor and into the condenser or receiver. Then the suction line, the discharge line, and any other refrigerant tubing connections are closed and disconnected from the compressor. The compressor is opened only while there is a slight

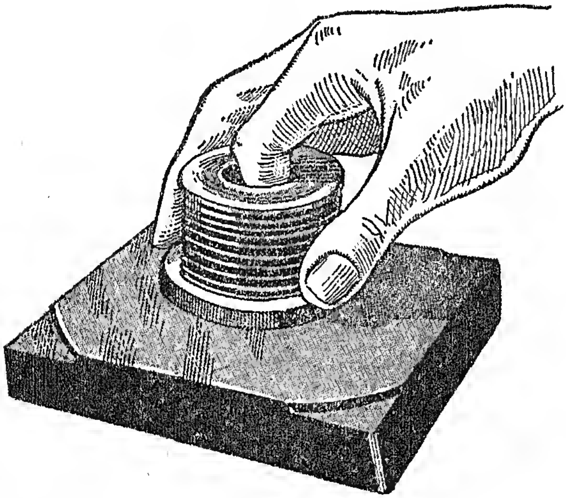

Fig. 120.—Lapping the Collar of a Seal Bellows.

positive internal pressure, thus reducing the admission of air and moisture.

To pump out the compressor proceed as follows, referring to Fig. 121:

1. Attach a compound gage to the suction service valve.

2. Start the compressor and gradually close the suction service valve to prevent violent foaming of crankcase oil as refrigerant separates from it.

3. After the suction service valve is completely closed, let the compressor run until the greatest possible vacuum is obtained.

4. Stop the compressor and immediately close the discharge service valve.

5. If the compound gage shows the vacuum decreasing rapidly toward zero it indicates that a considerable amount of refrigerant is being released from the crankcase oil. Repeat steps *2*, *3* and *4* above.

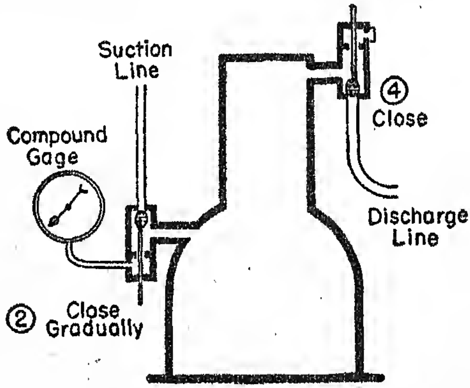

Fig. 121.—Some Steps During Pumping Out of the Compressor.

6. When the vacuum decreases slowly, indicating that most of the refrigerant is out of the oil, allow the low-side pressure to rise to one or two pounds above zero. Then the refrigerant lines may be disconnected and the compressor opened.

If the compressor is damaged to the extent that it cannot be run for pumping out, close the suction and discharge service valves, then allow refrigerant to escape from the compressor by opening the gage ports on the service valves.

In any case, close both service valves, leave the tubing lines attached to the valves, and remove the

valves from the compressor as in Fig. 119. Disconnect any other refrigerant lines, such as those for pressure controls, and plug the open ends of these lines. If the compressor does not have a discharge service valve, but has only a shutoff valve in the head, the entire head may be removed after this shutoff valve is closed—leaving the discharge line connected to the valve.

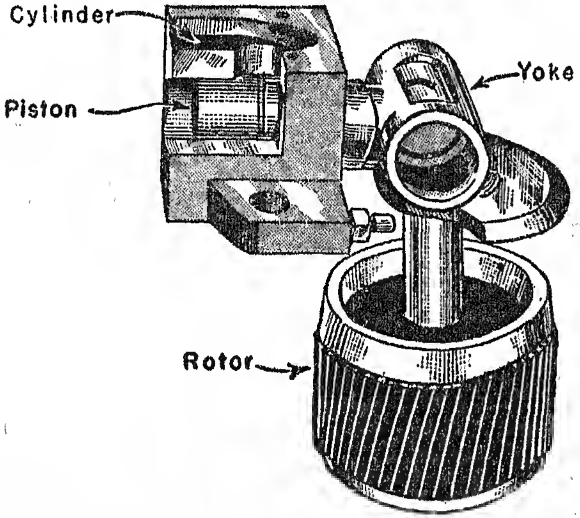

Fig. 122.—Scotch Yoke Construction in a Compressor.

Compressor Disassembly and Repair.—The exact manner in which any compressor is disassembled depends on its construction, and there are many differences in construction. The greatest enemies of refrigeration parts are moisture and dirt, so extreme cleanliness must be observed in every step. Parts removed should be immediately wrapped in clean cloths or heavy waxed paper. Every single part removed should be marked as to its exact

position; observing right or left, top or bottom, inside or outside, and every other possible identification. Many peculiar constructions will be encountered, such, for example, as the Scotch yoke and piston shown connected to a motor rotor in Fig. 122.

The flywheel should be removed immediately if it projects beyond the compressor body so that striking the wheel might spring the crankshaft. Mark the flywheel position with reference to the shaft, for the wheel has been balanced. Most flywheels are attached with a tapered fit, a key, washers and locking nuts. Always use a wheel puller. Hammering or bumping the shaft may spring it or may damage the shaft seal.

Measure all oil that is drained from the compressor, so that an equal quantity may be replaced. Discard the drained oil. Clean an oil strainer carefully so that the screen won't be damaged or displaced. Wrap the strainer to keep it clean.

Pistons and Rings.—Leaking piston rings sometimes may be corrected by installing new rings, while again both the rings and piston must be replaced. Worn cylinders sometimes are repaired by regrinding or lapping them and then using an oversize piston and rings. All these operations are similar to those performed on automobile engine parts.

Bearings.—Loose piston pin bearings seldom can be corrected with new pins alone; it usually requires a new piston as well. Split bearings with a removable cap may be tightened by removing shims or by carefully draw-filing the edges of the cap provided there is very little original looseness. This method leaves the bearing slightly out of round. New bearing liners are preferable. If the shaft surfaces are worn or scored the shaft should

be replaced with a new one, or else the old shaft reground and new undersized bearings fitted.

Rotary Compressors.—The blades and springs of a rotary compressor must be replaced in their exact original positions. If the parts are not already numbered, they must be clearly marked. Whereas the reciprocating compressor may have worn pistons, rings and cylinders, the rotary may have worn blades, rotor and casing. Clearances for rotors and casings usually are from two to four thousandths of an inch. Weak or broken blade springs must be replaced, although blade springs sometimes are carefully stretched to lessen the clearance of the blades.

Assembling the Compressor.—Before the compressor is re-assembled, all the parts, both new and old, are to be thoroughly washed in carbon tetrachloride or other cleaning fluid and allowed to dry without wiping. Then the parts are rinsed in the cleaning fluid and wiped dry with a hard lint-free cloth or with a clean chamois skin.

Clean all surfaces on which gaskets will rest. New gaskets are used practically everywhere with the possible exception of the head gaskets. Head gaskets, if new, must be of the same thickness and material as the originals so that clearance above the piston will not be altered.

As the compressor is being assembled, a coating of clean compressor oil should be applied to valves, valve seats, and sealing surfaces of shaft seals.

After the compressor is assembled, oil is put into the crankcase and the compressor is run from a shop motor for at least an hour to insure that pistons and bearings are free. With spare service valves in place the compressor may be tested for leaks by admitting compressed air, at about 40 pounds per square inch pressure, through the valve

ports with the valves closed. Air through the discharge valve will leak past defective discharge valves. Air through the suction valve will leak through a shaft seal. Soap solution is used for testing.

The assembled compressor is placed on its regular mounting in the condensing unit or refrigerator. The compressor must be fully charged with lubricating oil. Assuming that the service valves were closed to retain the refrigerant before the valves were taken off the compressor, these valves now are re-attached with new gaskets and any other refrigerant tubing connections are made complete. The compressor now is evacuated and purged as follows:

1. Attach a compound gage to the suction service valve, keeping the valve closed.

2. With the discharge service valve closed, take out its gage port plug or cap.

3. Run the compressor with both service valves closed until the maximum possible vacuum is obtained.

4. Stop the compressor and immediately open the suction service valve slightly to let refrigerant go through the compressor and out of the discharge service valve gage port to purge remaining air.

5. Attach a pressure gage to the discharge service valve. Open the discharge service valve and the suction service valve.

6. Test for leaks at all joints which have been disturbed.

7. Check the refrigerant charge by operating the system in a normal manner while observing the low-side and high-side pressures. Check the oil level in the crankcase.

CHAPTER 13

VALVES, EVAPORATORS AND CONDENSERS

The thermostatic expansion valve operates to maintain evaporation of refrigerant throughout the whole length of evaporator tubing, or almost to the point at which the thermostatic bulb is attached. Parts of the evaporator tubing in which refrigerant is evaporating will become covered with

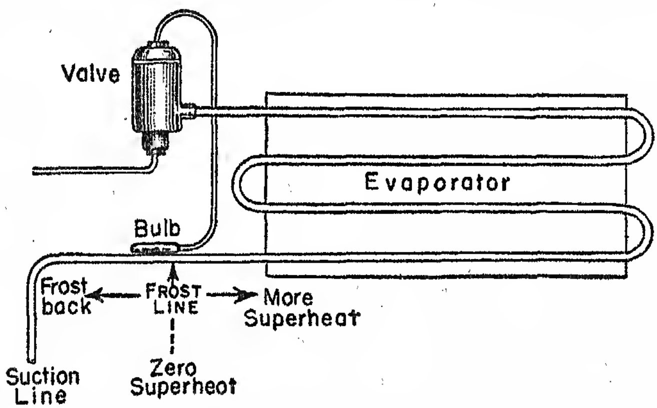

Fig. 123.—The Position of the Frost Line Changes with Variations of Superheat.

frost, and, as a result, the point beyond which there is no evaporation is roughly indicated by the frost stopping at that point.

Minimum temperature of the evaporator tubing occurs where there is frosting, and beyond the frost line the temperature rises. The thermostatic expansion valve may be adjusted to open and close when a certain temperature exists at the thermal

bulb. Thus the valve adjustment determines the temperature of the evaporator tubing at the point where the bulb is attached. The difference between the bulb temperature and evaporation temperature is called superheat, or the number of degrees that the bulb temperature is above evaporation temperature is the superheat.

If the valve is adjusted for zero superheat it will

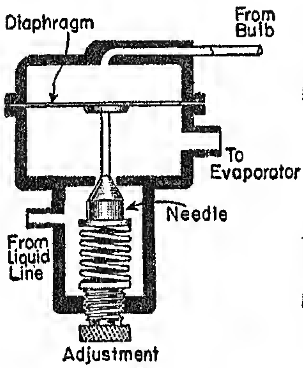

Fig. 124.—Adjustment Principle of a Diaphragm Type Thermostatic Expansion Valve.

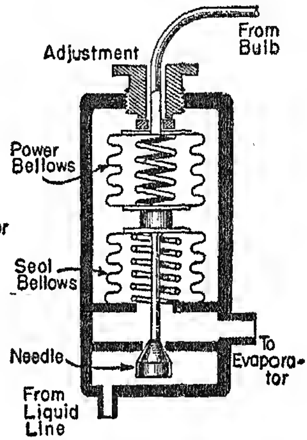

Fig. 125.—Adjustment Principle of a Bellows Type of Thermostatic Expansion Valve.

admit enough refrigerant to the evaporator to bring the frost line all the way to the bulb position, as in Fig. 123. If the valve is adjusted to admit less refrigerant, the evaporation and frosting will not extend so far as the bulb position, the bulb will be warmer than the evaporation temperature, and there will be a certain amount of superheat. The less refrigerant admitted the greater will be the superheat and the farther from the bulb will be the

frost line. If the valve is adjusted to admit too much refrigerant, the evaporation will continue on past the bulb and the frost line will extend from the evaporator toward and onto the suction line.

Thermostatic Expansion Valve Adjustment.—Thermostatic expansion valves of the diaphragm type commonly have an adjustment whose principle is shown by Fig. 124. The adjusting screw or nut

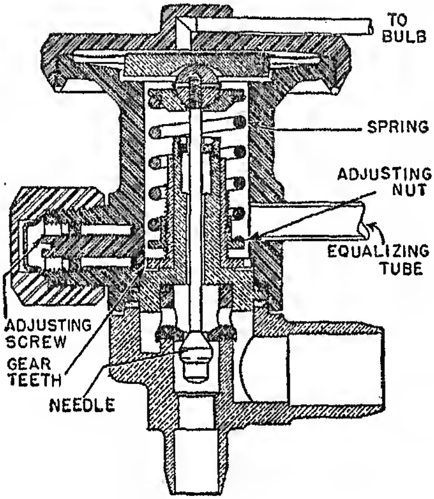

Fig. 126.—Diaphragm Type Thermostatic Expansion Valve with Geared Adjustment.

alters the tension of a spring which tends to hold the valve closed. Rise of temperature at the bulb increases the pressure in the bulb and above the diaphragm, and tends to open the valve. The greater the spring tension the more pressure and higher bulb temperature are required to open the valve. Thus an increase of spring tension increases the superheat and keeps the frost line farther from the bulb or farther back on the evaporator tubing.

Less tension reduces the superheat and allows the frost line to come closer to the bulb or even beyond the bulb.

Thermostatic expansion valves of the bellows type often have adjustments whose principle is illustrated by Fig. 125. Here the spring which is inside the seal bellows tends to keep the valve closed. The valve is opened by increase of temperature at the bulb, which results in increased pressure in the bulb and in the power bellows. Turning the adjusting nut clockwise, to the right, or toward the valve body, tends to open the valve. Such an adjustment admits more refrigerant to the evaporator, reduces the superheat, and allows the frost line to come closer to the bulb or out beyond the bulb. Turning the adjustment counter-clockwise, to the left, away from the valve body, will reduce the refrigerant flow, will increase the superheat, and will keep the frost line farther back from the bulb.

Fig. 126 shows a diaphragm type of valve in which the spring opposes downward distention of the diaphragm and tends to keep the valve closed. Spring tension is adjusted with a threaded collar which is rotated by gears that may be turned with a slotted stem after removal of the seal cap. Many thermostatic expansion valves have no service adjustment, being set when manufactured to maintain a certain number of degrees of superheat.

Adjustable thermostatic expansion valves usually are adjusted as follows:

1. Operate the system for at least several cycles during which the compressor is started and stopped by action of the temperature or pressure cycling control.

2. If the frost line now extends past the thermal bulb toward or onto the suction line, change the

adjustment from one-quarter to a full turn in the direction that reduces refrigerant feed, then run the system for a couple of cycles and again check the position of the frost line.

3. If the frost line does not come close enough to the thermal bulb, change the adjustment a quarter to a full turn in the direction to admit more refrigerant, then operate the system for a couple of cycles and check the frost line.

4. The minimum temperature of the refrigerated space is secured with zero superheat or with the frost line at the thermal valve. Slightly higher temperatures may be secured with adjustment for more superheat.

Adjusting the Superheat.—A thermostatic expansion valve may be completely tested and adjusted for any number of degrees of superheat with the setup of Fig. 127. The inlet side of the valve (the liquid line connection) is attached to a service cylinder of refrigerant or to a compressed air supply with a pressure gage anywhere on this connection. The purpose is to provide a pressure of 70 to 100 pounds per square inch during the tests. To the valve outlet (the evaporator connection) is attached a compound gage and a shutoff valve. The thermal bulb is completely immersed in cracked ice. The immersion must be in ice, not merely in ice water, because the bulb is to be maintained at a temperature of exactly 32°, which is the temperature of melting ice.

Determine the reading to be obtained on the compound gage as follows:

1. Subtract from 32° the number of degrees of superheat desired. For example; if the superheat is to be 10°, subtract 10° from 32° to have a difference of 22°.

2. Look at the table of temperatures, pressures

and latent heats for the refrigerant used in the system and find the gage pressure corresponding to the temperature difference determined in step *1* above. For example; with Freon-12 the gage pressure corresponding to 22° is 22.45 pounds or practically 22.5 pounds. The valve is to be adjusted to maintain this pressure reading on the compound gage.

The adjustment is made thus:

1. Open the shutoff valve just enough to let some gas or air continue to escape through it.

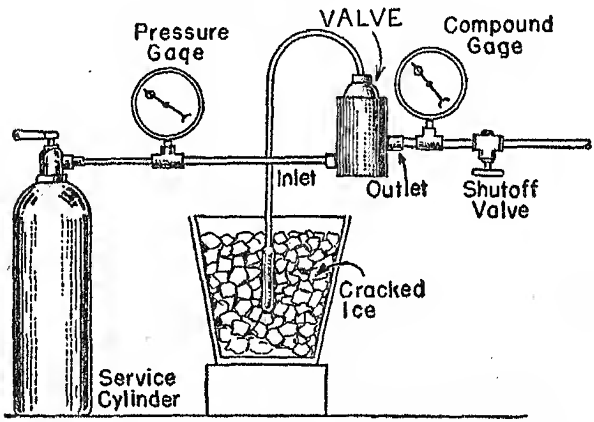

Fig. 127.—Adjusting a Thermostatic Expansion Valve for Superheat, and Checking the Action of the Valve.

2. Open the valve on the service cylinder or the compressed air supply enough to have a reading of at least 70 pounds on the pressure gage.

3. Adjust the expansion valve to maintain the required pressure on the compound gage while there is a slight leakage through the shutoff valve. Each time that the adjustment is changed, tap the expansion valve lightly to make certain that the

parts are moving freely. When the required pressure is maintained, the valve has been adjusted for the desired superheat.

Check operation of the expansion valve thus:

1. Close the shutoff valve. Compound gage pressure should rise a few pounds, then increase very slowly or stop rising. If pressure on the compound gage rises rapidly to that shown by the pressure gage, the valve is leaking.

2. Open the shutoff valve to permit a slight leakage. Take the thermal bulb out of the crushed ice and place it in water which is at about room temperature. If compound gage pressure does not now rise rapidly it indicates that the thermal bulb and power element have lost most or all of their charge.

3. Close the shutoff valve, leaving high pressures on both gages, and then test the body of the valve, its joints, and the connections for leaks.

Thermostatic Valve and Bulb Positions.—For medium temperature and high temperature applications the thermostatic valve usually feeds into the top of the evaporator as at *A* in Fig. 128, while for low temperature work the valve often feeds into the bottom of the evaporator as at *B*. The valve itself may be vertical, horizontal, tilted at an angle, or sometimes upside down. The valve may be either inside or outside the space being refrigerated, but the thermal bulb always must be inside the refrigerated space.

The thermal bulb should be attached to the suction line as near as possible to the point at which this line attaches to the evaporator, or else at the end of the evaporator tubing which connects to the suction line. The bulb must be tightly clamped to a portion of the tubing which has been well cleaned. As at *A* in Fig. 128, the tubing outlet from the bulb

should be upward when the bulb is on a vertical line. If the bulb is higher than the valve, as at *B*, there should be an upward loop in the tubing between bulb and valve. A bulb clamped to the bottom of the evaporator, as at *C* in Fig. 128, must not be where the suction line rises, because condensed refrigerant in the evaporator then will keep the bulb cold until this liquid evaporates.

The thermostatic valve body, with its bellows or diaphragm chamber, must remain warmer than the thermal bulb. Otherwise the refrigerant charge

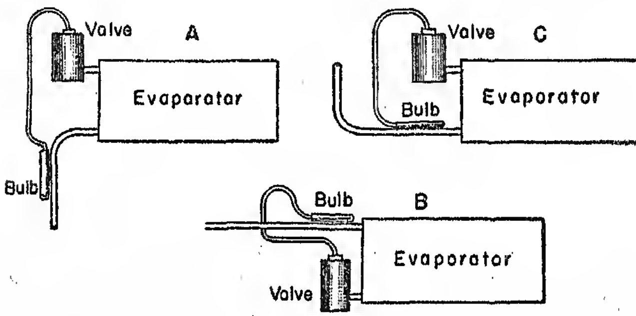

Fig. 128.—Thermostatic Valve and Bulb Positions with Reference to the Evaporator and Tubing Lines.

may condense in the bellows or diaphragm chamber and stop refrigeration. If warming the valve body with your hands allows refrigeration to continue, it indicates that the valve was too cold with reference to the bulb and that the valve should be located in a warmer place.

The bulb must not be exposed to currents of air or liquid that warm it more rapidly than the evaporator warms during an idle period of the compressor. Otherwise the warmed bulb may open the valve with the compressor idle, allow refrigerant to flow into the evaporator, and flood through into the

suction line when the compressor again starts.

Automatic Expansion Valve Adjustment.—The general construction and adjustment means in automatic expansion valves may be similar to those of thermostatic expansion valves except that pressure from the thermal bulb in the thermostatic type is replaced by atmospheric pressure in the automatic type. The principle of one style of automatic valve is illustrated by Fig. 129. Here the valve spring and vapor pressure from the evaporator tend to close the valve, while atmospheric pressure and

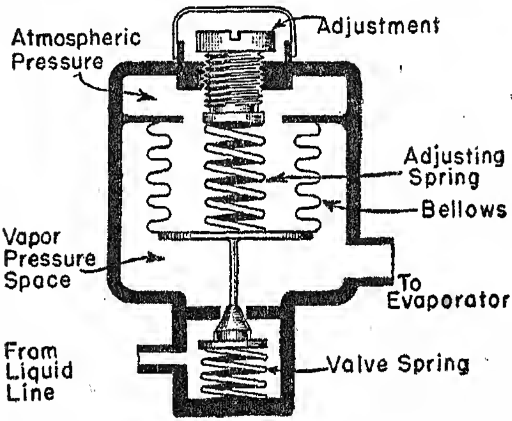

Fig. 129.—Adjustment Principle of an Automatic Expansion Valve.

tension of the adjusting spring tend to open the valve. Turning the adjustment screw clockwise, to the right, or toward the valve body will admit more refrigerant, while turning the screw out reduces the rate of refrigerant feed.

To adjust an automatic expansion valve proceed as follows:

1. Attach a compound gage to the suction service valve.

2. Adjust the expansion valve to reduce refrigerant flow to the minimum rate or to completely stop the flow.

3. Start the compressor, let it run for a few minutes, then open the expansion valve not more than a half turn at a time to gradually admit more refrigerant.

4. Each time the adjustment is changed allow the compressor to run until there is a steady gage reading. Continue the adjustment until the gage shows a pressure or vacuum corresponding approximately to the desired evaporating temperature as shown in the tables of refrigerant temperatures, pressures and latent heats. The pressure may be set about one-half pound higher than that which corresponds exactly to the temperature.

5. Let the system operate normally through two or three cycles. If frost runs out onto the suction line, reduce the refrigerant feed until the frost does not extend beyond the evaporator.

To test the valve for leakage continue as follows:

1. Close the receiver valve or the liquid line shut-off valve.

2. Run the compressor to obtain the maximum possible vacuum in the low side.

3. Watch the compound gage while opening the valve to the liquid line. If the expansion valve does not leak, the pressure will rise slightly higher than normal and then drop back to normal. A leaky valve will allow the pressure to rise well above normal and remain high.

Flushing an Expansion Valve.—A leaky expansion valve in which the trouble results from dirt, or a clogged expansion valve, sometimes may be returned to normal operation by flushing. Following is one method.

1. Attach a compound gage to the suction service valve.

2. Adjust the expansion valve to reduce the refrigerant flow as much as possible. Be sure to count the number of turns and fractions of a turn that the adjustment is changed, so that the valve may be returned to this original setting.

3. Run the compressor to produce a low-side vacuum of 20 inches or more.

4. With the compressor still running, open the expansion valve wide (counting the number of turns and fractions) and immediately return the adjustment to its original setting in order to avoid flooding of refrigerant through the evaporator.

5. Check the performance of the system. Repeat the flushing once or twice if the trouble was not corrected. If there is still no improvement the valve must be disassembled for repairs.

Another method of flushing is as follows:

1. Attach a compound gage to the suction service valve.

2. Close the receiver valve or the liquid line shut-off valve.

3. Run the compressor to produce a low-side vacuum of 20 inches or more.

4. Almost close the suction service valve (to prevent flooding later on).

5. Adjust the expansion valve for the maximum flow of refrigerant; being sure to count the turns and fractions that the adjustment is changed.

6. Open the receiver valve or liquid line valve suddenly and fully, and immediately stop the compressor.

7. Return the expansion valve adjustment to its original setting.

8. Start the compressor, and, as frost disappears

from the suction line, open the suction service valve.

9. Test the operation of the system, and repeat the flushing once or twice if necessary. If there is no improvement it will be necessary to disassemble the expansion valve for repairs.

Removing and Replacing an Expansion Valve.—To remove and replace an expansion valve proceed as follows. Fig. 130 indicates the parts.

1. Have ready the new or replacement expansion valve, well cleaned, dried and warmed. Have also a new gasket for the valve if there is a gasketed

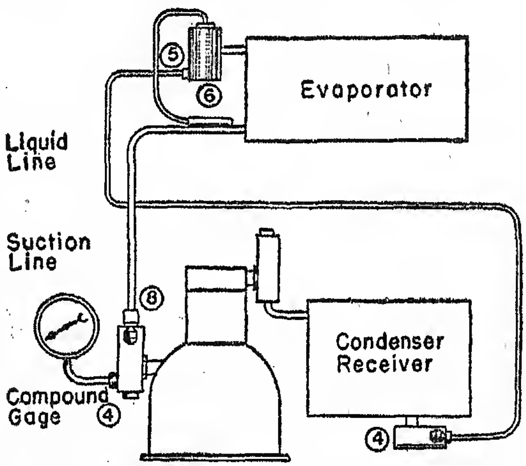

Fig. 130.—Some of the Steps in Removing and Replacing an Expansion Valve.

joint. Clean and dry all the connections which will be opened.

2. Attach a compound gage to the suction service valve.

3. Pump down the system and balance the low side pressure to between zero and two pounds, with the evaporator warm.

4. Close the suction service valve and the receiver valve to the liquid line.

5. Disconnect the liquid line at the expansion valve and plug the end of the line.

6. Remove the expansion valve from the evaporator, and the bulb from the suction line. Immediately attach the new valve, or, if there is to be any delay, plug the opening into the evaporator. Attach the liquid line to the valve.

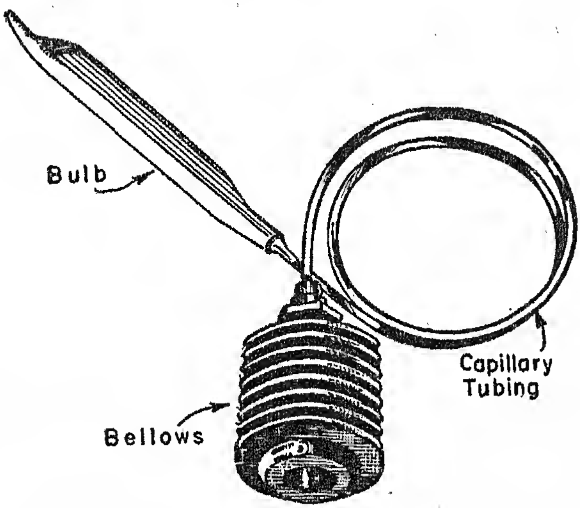

Fig. 131.—A Thermostatic Power Element.

7. Adjust the expansion valve so that it will remain open as far as possible and admit refrigerant to the evaporator.

8. Loosen the flare nut where the suction line attaches to the suction service valve.

9. Crack the receiver valve or liquid line shutoff valve to let refrigerant come all the way through and emerge from the loosened flare at the suction service valve. Tighten the flare nut.

10. Test for leaks at all joints which have been disturbed. Close any leaks.

11. Open the suction service valve and liquid line valve.

12. Adjust the expansion valve for normal operation.

From some thermostatic expansion valves it is possible to remove the complete power element without detaching the valve from the evaporator or removing the liquid line from the valve. The power element consists of a bellows, connecting tubing, and bulb, as shown by Fig. 131, or of a diaphragm with its housing and the connecting tube and bulb. Such power elements may be removed and replaced after the system is pumped down and the low-side pressure balanced.

Checking a Power Element.—To check the operation of the power element of a thermostatic expansion valve proceed thus:

1. Detach the thermal bulb from the suction line or evaporator tubing.

2. Melt off any frost remaining on the tubing where the bulb was attached, then with one hand grasp the suction line or evaporator tubing at this point, so that changes of temperature may be felt.

3. Grasp the detached thermal bulb in the palm of your other hand to warm the bulb. If the power element is operating, the valve will open, refrigerant will come through the evaporator, and you will feel the drop of temperature in the suction line or evaporator tubing. If there is no decided drop of temperature it indicates that the power element has lost its charge, or possibly that the flow of refrigerant is obstructed at the valve or elsewhere.

Expansion Valve Repairs.—An expansion valve which persists in leaking after having been flushed once or more is preferably repaired by insertion of

a new needle and new seat. In some valves the needle and seat are in a removable unit.

Emergency repair sometimes may be effected by thoroughly cleaning the needle and seat, then holding the needle accurately centered on the seat and lightly tapping the needle with a small hammer. It also is possible to place lapping compound on the seat and then to rotate the needle back and forth on the seat. Rotate farther one direction than the other so that the needle is gradually turned around

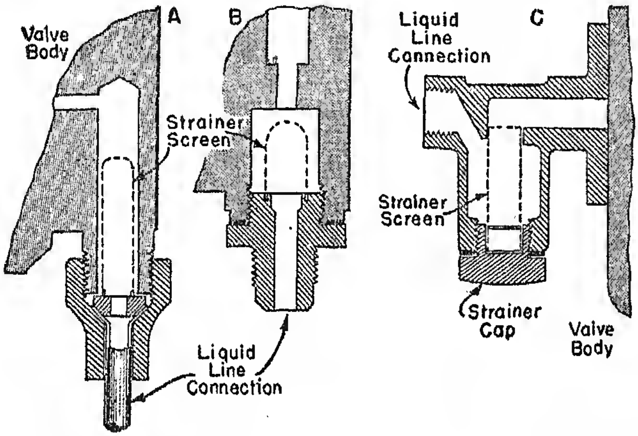

Fig. 132.—Methods of Attaching Strainer Screens to Valve Bodies.

and around. Finally wash the parts in carbon tetrachloride or other cleaning fluid.

Weak, twisted, corroded, or otherwise damaged valve springs should be replaced with new ones, since it is practically impossible to restore such a spring to its original action in service. Gaskets, unless perfectly smooth, should be replaced.

Cleaning Valve Strainers.—Most expansion valves and other refrigerant control valves have strainers

built in or attached to the valve body. Several designs are shown by Fig. 132. At *A* the strainer screen is removed by taking off the flare nut that holds the liquid line on the valve. At *B* the strainer is carried by a separate fitting which may be removed from the valve body after the liquid line has been disconnected from this fitting. At *C* the strainer unit is separate from, and bolted to, the valve body. The strainer may be removed for cleaning by taking off the strainer cap, without loosening or detaching the liquid line.

To remove a strainer for cleaning proceed as follows:

1. Pump down the system and balance the low-side pressure.

2. Clean and dry the valve body and the connections or caps to be removed.

3. Remove and wash the filter screen. Replace the screen, making sure that gasketed joints are in good condition. Re-attach the liquid line if it has been removed.

4. Adjust the expansion valve so that it will remain open as far as possible. Be sure to count the turns and fractions that the adjustment is changed.

5. Loosen the flare nut where the suction line attaches to the suction service valve.

6. Crack the receiver valve or liquid line shutoff valve until refrigerant comes out at the loosened flare nut. Tighten the flare nut.

7. Return the expansion valve adjustment to the original setting. Operate the system and check its performance.

Low-side Float Valve Service.—Float valves of any type must be mounted in chambers which are level and which are not subject to excessive vibration. Liquid levels which are once correct seldom change unless there is a complete failure of the

valve or the float. Some float headers have level adjustments accessible from the outside, others have screw adjustments inside, and many have no means for adjustment other than bending of the float arm downward to lower the liquid level or upward to raise it.

A float valve which is sticking either closed or open sometimes may be released by jarring the float chamber or header with a piece of wood held against the header while lightly struck with a small hammer. Such troubles may be corrected also by flushing the valve. A test for a valve remaining closed is made by closing the receiver or liquid line valve, running the compressor ten or more minutes to lower the liquid level, then opening the liquid line valve while listening at the float valve. If no rushing sound is heard the valve probably is stuck closed.

A low-side float valve may be flushed by following the second method of flushing as outlined for an expansion valve, omitting steps *5* and *7* which apply only to an expansion valve.

Removing a Low-side Float Valve.—The cover plate for the evaporator header in a low-side float system may have shutoff valves on the plate for both the liquid line and suction line as in Fig. 133. If there are no header valves the two lines may be closed only at the receiver or liquid line valve and at the suction service valve.

Before commencing to remove and replace a float valve have all the new parts, including a new gasket, in readiness—thoroughly dry and warmed. Clean and dry all joints around the header plate. If the valve end of the header can be tilted upward it will help retain oil in the header while the plate is off.

The removal and replacement are carried out as follows:

1. Install a compound gage on the suction service valve.

2. Close the receiver liquid line valve or the liquid header valve.

3. Run the compressor until the low-side vacuum reaches 15 to 25 inches and until the evaporator is warm. This may take two or three hours.

4. Crack the liquid line valve to balance the low-

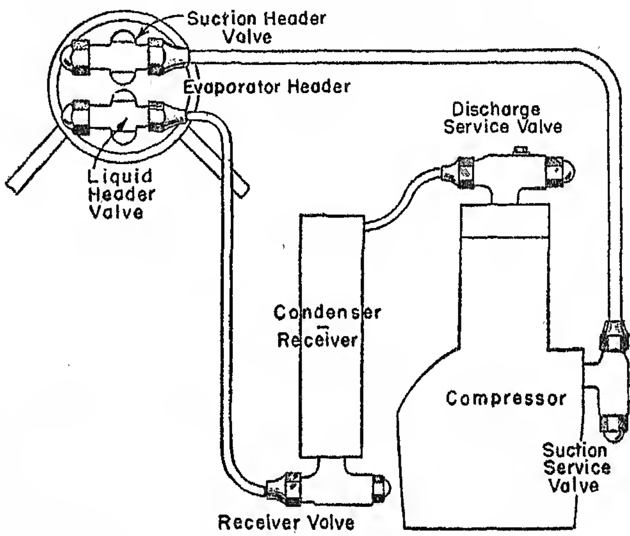

Fig. 133.—Positions of Shutoff Valves Which May Be Found in a Low-side Float System.

side pressure at just above zero, then close this valve.

5. Close the suction service valve or the suction header valve.

6. Remove both header valves from the plate with the liquid and suction lines attached to their valves, or, if there are no header valves, disconnect and plug the liquid and suction lines.

7. Loosen but do not remove all the header plate screws, tap around the joint, and then take out the screws and remove the plate with the valve and float. Goggles always should be worn during this step so that refrigerant will not get in your eyes.

8. Clean the gasket seating surface on the header, install the new or replacement unit, and tighten the screws evenly.

9. Reattach the liquid and suction lines at the header plate.

10. Close the suction service valve, if not already closed, and loosen the flare nut for the suction line at this valve.

11. Crack the receiver valve or the liquid header valve until refrigerant comes out of the loosened flare connection, then tighten the flare nut.

12. Test the system for leaks.

In some types of equipment the float valve seat may be removed without taking off the header plate, the seat being exposed by removal of a cap or by taking off the liquid header valve after this valve has been closed to seal the liquid line. Removal and replacement are essentially as just outlined, except that the header plate is not taken off.

The complete evaporator for a low-side float system may be removed and replaced by following the procedure just outlined for removal and replacement of the float valve, except that steps *7* and *8* would consist merely of the dismounting and remounting of the evaporator. In some systems the capacity of the condenser or receiver may not be great enough to take the entire refrigerant charge of flooded evaporators, in which case refrigerant will have to be removed into service cylinders.

Replacing a Dry Evaporator.—The steps in removal and replacement of a dry evaporator with expansion valve are as follows:

1. Install a compound gage on the suction service valve.

2. Pump down the system, balance the low side pressure after the evaporator has warmed up. Leave the liquid line valve closed.

3. Adjust the expansion valve for maximum flow of refrigerant, counting the turns and fractions if the valve previously has been correctly adjusted.

4. Close the suction service valve, disconnect the suction line from the evaporator, and plug the open end of the line.

5. Remove the expansion valve from the evaporator, leaving the liquid line attached to the valve.

6. Dismount the evaporator and install the replacement unit.

7. Clean and dry the evaporator connections, then attach the suction line and the expansion valve.

8. Loosen the flare nut where the suction line joins the suction service valve, then crack the receiver valve or liquid line valve until refrigerant issues from the loosened flare joint. Tighten the flare nut.

9. Check for leaks at all joints which have been disturbed.

10. Return the expansion valve adjustment to its original setting.

Defrosting Evaporators.—Frost ordinarily is removed from an evaporator before the thickness exceeds three-sixteenths to one-quarter inch, thus avoiding short cycling and other operating troubles. Any evaporator may be defrosted by shutting off the compressor until the frost melts away. Individual evaporators in multiple systems are defrosted by closing their liquid line connections until the frost melts off. Frost frequently is removed from piping or tubing of bare steel by scraping with metal tools, but scraping should not be done on a

copper tube, and only with great care on galvanized piping.

When an evaporator must be defrosted without allowing the refrigerated space to become warm the evaporator may be heated with hot refrigerant gas. A method for thus defrosting a dry evaporator is illustrated by Fig. 134. From the gage port on the discharge service valve a ⅜-inch hot gas line is run to the top of a tee inserted between the expansion valve and the evaporator. In the hot gas line is a shutoff valve *H*. A shutoff valve *L* is placed in

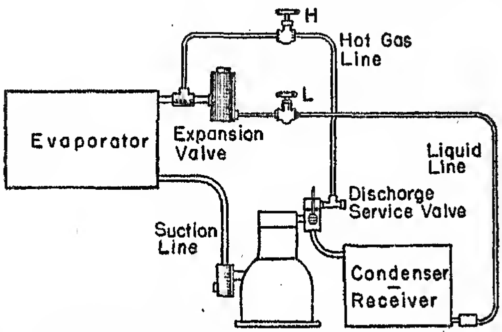

Fig. 134.—Valves and Connections for Defrosting a Single Evaporator by Means of Hot Gas.

the liquid line. The discharge service valve is wide open, back seated, while connections are made, then is turned about one and one-half turns toward the closed position and left there.

To defrost the evaporator the compressor is started, liquid line valve *L* is closed, hot gas valve *H* is opened, and the compressor continued in operation until the frost is melted away. Then valve *H* is closed and valve *L* opened slowly, with the compressor still in operation. The frost absorbs latent heat of condensation from the hot gas, and if valve *H* is opened too far there will be condensed liquid

refrigerant pumped back into the compressor to cause knocking or pounding.

Fig. 135 shows a hot gas defrosting connection for two evaporators, numbered *1* and *2*. The hot gas line runs from the discharge service valve, or any point on the discharge line, through shutoff valves *H-1* and *H-2* to the suction line connections of the evaporators. Shutoff valves *S-1* and *S-2* are between the hot gas connections and the suction line

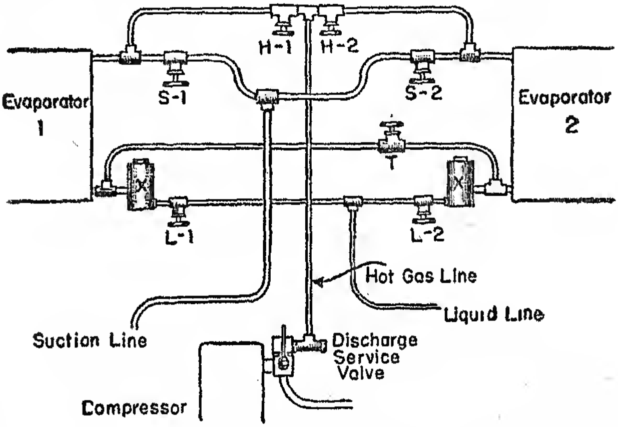

Fig. 135.—Hot Gas Defrosting Connections for Two Evaporators.

to the compressor. Shutoff valves *L-1* and *L-2* are between expansion valves *X-X* and the liquid line. A line in which is valve *T* connects together the inlets of the two evaporators.

For normal operation valves *H-1*, *H-2* and *T* are closed, and all the others are open, as at *A* in Fig. 136. To defrost evaporator *1*, leave *H-2* closed and *S-2* open, as at *B*. Close *L-1* and *L-2* to shut off the liquid lines, and close *S-1* to close the suction line for evaporator *1*. Open *H-1* to admit hot gas to evaporator *1*. The gas is condensed to liquid as the

frost melts. The liquid refrigerant is expanded into evaporator *2* by opening valve *T*, and the vapor is drawn from evaporator *2* by the compressor. At completion of the defrosting process, close valves *T* and *H-1*, and open valves *S-1*, *L-1* and *L-2*.

To defrost evaporator *2*, and admit condensed refrigerant to evaporator *1*, the process is similar except that valves *H-2* and *S-2* are manipulated instead of valves *H-1* and *S-1*.

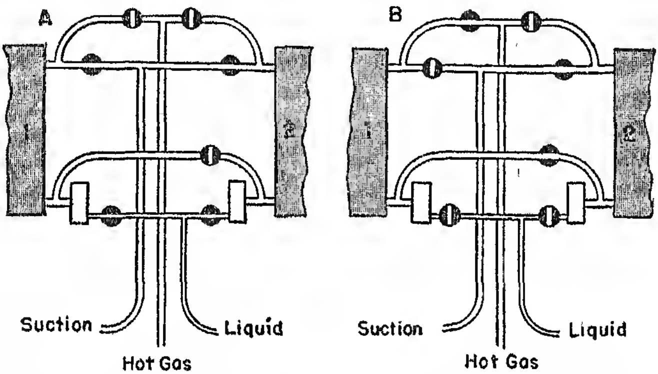

Fig. 136.—Valve Positions for Normal Refrigerating Operation (A), and for Defrosting (B) with Hot Gas for Two Evaporators.

Condenser Replacement.—If the condenser acts also as a receiver it is necessary to remove all refrigerant from the system when replacing the condenser. The procedure is as follows:

1. Pump down the system and balance the low-side pressure.

2. If there is a liquid line shutoff valve at the condenser outlet, close this valve, also close the discharge service valve, connect a service cylinder to the condenser outlet (after removing and plug-

ging the liquid line) and remove the refrigerant from the condenser in the usual manner.

3. If there is no liquid line shutoff valve it may be possible to disconnect the liquid line at some point toward the evaporator and remove the refrigerant from that connection of the liquid line. It is possible also to remove the refrigerant as vapor through the gage port of the discharge service valve with the suction service valve closed.

4. With the condenser replaced and all connections completed, the system is to be evacuated, then charged with refrigerant, tested for leaks, and purged if this appears necessary when the system is operated and pressures noted.

With a separate receiver the condenser is removed and replaced thus:

1. Pump down the system and balance the low-side pressure. Leave the receiver liquid line valve closed.

2. If there is a shutoff valve between the condenser and the receiver, close this valve, close the discharge service valve, and remove the condenser. If there is no shutoff valve between condenser and receiver, close the discharge service valve, disconnect the condenser from the receiver, and plug the opening to the receiver.

3. With the condenser replaced and connections completed, open the valve between condenser and receiver, if there is such a valve, remove the gage plug from the discharge service valve, and purge air from the condenser through this port by opening the discharge service valve.

4. Test for leaks in the regular manner, place the system in operation, and observe the operating pressures to note whether purging is needed.

CHAPTER 14

CYCLING CONTROL SERVICE

Cycling controls are switches which start the compressor when temperatures or low-side pressures rise to some predetermined value, and which stop the compressor when temperatures or pressures decrease by an amount determined by the range adjustment. It is a general rule that operating temperatures or pressures are lowered by decreasing the tension of a spring in the control unit, and are raised by increasing the spring tension. Solenoid valves follow the same general rule.

The range adjustment usually is the same as, or is associated with, any manual temperature adjustment which is provided. The range usually may be adjusted independently of the manual control, so that movement of the manual control varies the range at higher or lower levels of temperature. This often is done simply by removing the knob or pointer of the manual control and replacing it in a new position on its shaft, so that thereafter the manual control will either increase the spring tension more than before (to obtain higher temperatures) or else will decrease the spring tension more than before to obtain lower temperatures.

The range ordinarily should be adjusted before the differential is changed. The differential adjustment very seldom should be changed on a domestic refrigerator, but may require change on commercial installations to accommodate various classes of service. Several types of range and differential adjustments were discussed in an earlier chapter. The differential sometimes is changed by altering the gap between switch contacts; loosening the lock

on an adjustable screw and turning the screw. More gap gives a greater differential; less gap gives a smaller differential.

Adjustment of either the range or the differential usually affects the other, so the range should be checked after a differential adjustment, and the differential checked after a range adjustment. After operating temperatures or pressures are satisfactory all of the locking nuts or screws should be tried to make certain that they are secure.

Pressure-type Control Adjustment.—A method of adjusting the range and differential of a low-side pressure control is as follows:

1. Attach a compound gage to the suction service valve.

2. Set the range adjustment for the lowest pressure, and the differential adjustment for the greatest differential.

3. Start the compressor and operate it until the compound gage shows the desired pressure or vacuum for cut-in or for starting the compressor in normal operation.

4. Change the range adjustment until the control just cuts out and stops the compressor.

5. Move the range adjustment slowly in the opposite direction until the control just cuts in and starts the compressor. This sets the cut-in point.

6. Let the compressor run until the gage shows the pressure at which cut-out is desired.

7. Adjust the differential slowly until the control just cuts out. This sets the cut-out point.

8. Let the system operate normally through at least one complete cycle, and on the next cycle note the gage pressures, or vacuums, at which cut-in and cut-out occur. Slight readjustments then may be made.

Thermal Bulb Controls.—A temperature control

type or thermostatic type of cycling control may be adjusted in a manner generally similar to that followed for a pressure control, except that a thermometer is used instead of a compound gage. If operation is to be in accordance with air temperature or a liquid bath temperature, the thermometer is placed at the thermal bulb position. If evaporator temperature is to be checked the bulb of the thermometer may be allowed to freeze to the evaporator by putting on a few drops of water while the bulb of the thermometer is held on a spot free of frost. The thermometer may be removed later with a cloth wet with warm water. The procedure then will be as follows:

1. Set the range adjustment for the lowest temperatures and the differential for the greatest change of temperature.
2. Run the compressor until the thermometer shows the desired temperature for cut-in or for starting the compressor in normal operation.
3. Alter the range adjustment until the control just cuts out and stops the compressor.
4. Move the range adjustment slowly in the opposite direction until the control just cuts in and starts the compressor. This sets the cut-in point.
5. Let the compressor run until the thermometer shows the desired cut-out temperature.
6. Adjust the differential slowly until the control just cuts out to stop the compressor. This sets the cut-out point.
7. Check cut-in and cut-out temperatures on one or two following cycles of normal operation.

A temperature type cycling control always should start the compressor when you warm the bulb with your hand. Otherwise the bulb and bellows may have lost their charge. A leaky or discharged bellows will feel soft and is easily compressed when

it is warm, while one in good condition will be so hard when warm that it can be compressed little if at all.

Since a thermal bulb control responds to temperature changes, regardless of the kind of refrigerant used in the system, the same bulbs may be used with any system. The same suction pressure bellows or diaphragm element may be used with any of the common refrigerants in a low-side pressure control.

Temperature Control Mountings.—Some general rules applying to temperature controls with thermostatic bulbs are as follows: As at *A* in Fig. 137, a bellows or diaphragm should be at the bottom or on the side of the switch unit rather than on top of the unit. As indicated at *B* the switch unit should not be subjected to any temperature lower than 20°, otherwise there is danger of frost collecting inside the unit and interfering with its operation. No part of the tubing between the switch and the bulb should get colder than the bulb, as might happen were the tubing near a suction line.

As shown at *C* in Fig. 137, the switch unit may be mounted outside the refrigerated space with the thermal bulb inside the space. When regular thermal bulbs are used, the temperature at the bellows or diaphragm unit always should be at least 10° higher than at the bulb, so that control is in accordance with bulb temperature rather than with bellows or diaphragm temperature. If the temperature difference must be less than 10°, or if the bulb may be warmer than the bellows or diaphragm, a special type of large bulb should be used.

Thermal bulbs for control of air temperature should be at least two or three inches from any metal or wood, and never should touch such members. These bulbs should be located where there will be the greatest changes of air temperature, or

in parts of a cabinet which will warm to the highest temperature. However, they must not be exposed to warm drafts from opened doors. Bulbs attached to evaporators must be firmly clamped to a spot which is clean and smooth, with no burrs, solder spots, or other roughness holding the bulb away from the evaporator surface.

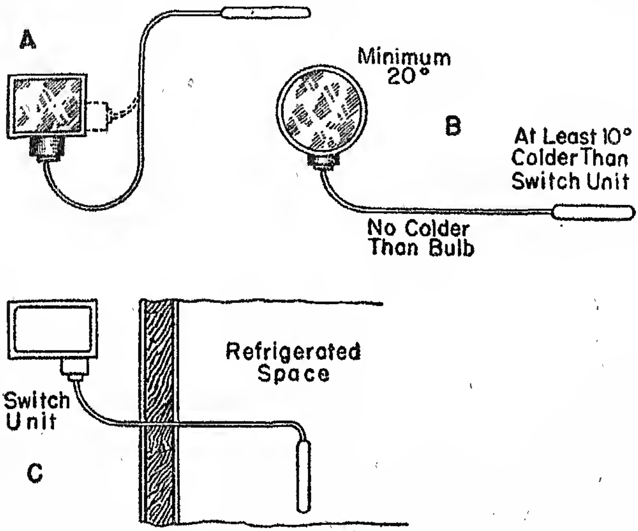

Fig. 137.—Precautions to Be Observed When Mounting Temperature Control Bulbs.

Thermal bulb tubing must not be cut, and must be guarded from possible sharp bends or kinks. If the tubing is longer than needed the excess should be carefully coiled and taped or otherwise fastened near the switch unit.

Mercury Switches.—Controls which incorporate mercury switches must be mounted vertically and level. The mounting position may be checked with a small spirit level held on some portion of the

mounting which evidently is supposed to be truly horizontal. Some switches, as in Fig. 65, have a hanging pendulum whose lower tip must register with a mark in the case. Because of these requirements, mercury switch controls are not suitable for portable or mobile equipment.

The mercury tube ordinarily should be exactly centered lengthwise in its clips. Tilting should be to the same degree in both directions, so that the mercury will rise to approximately the same height in each end of the tube.

Mercury tubes which are cemented into their clips may be removed by taking out the locking wires, then prying carefully between the tube and each side of each clip to break the cement. Cement is not required when a tube is replaced in the clips. The portions of the tube held by the clips may be wrapped with one or two layers of friction tape and put in place.

Altitude Effect.—Any control employing a bellows or diaphragm with one side exposed to atmospheric air pressure is affected to some extent by changes of altitude. Consequently, altitude has an effect on both low-side pressure controls and on thermostatic temperature controls. Controls ordinarily are adjusted for the altitude of the factory making them, or making the refrigeration apparatus. When used at higher altitudes the operating temperatures or pressures will be lower than the original values, and when used at lower altitudes the operating temperatures or pressures will be raised.

Maximum atmospheric air pressure is at sea level or at zero altitude, and air pressures decrease as we go to higher altitudes. It is this atmospheric air pressure that acts on the outside of a bellows or diaphragm, and opposes the internal vapor pressure coming from the low side or from a thermal bulb.

With the same vapor pressure and temperature, changes of altitude have the effects shown by Fig. 138. The lessened air pressure at higher altitudes allows greater expansion of the bellows or diaphragm, and the control operates more quickly, or at lower vapor pressure and temperature. Greater air pressures at lower altitudes tend to compress the bellows or diaphragm, and the control operates later or at higher vapor pressure and temperature.

Were a control graduated in temperatures or pressures, operation at higher altitudes would re-

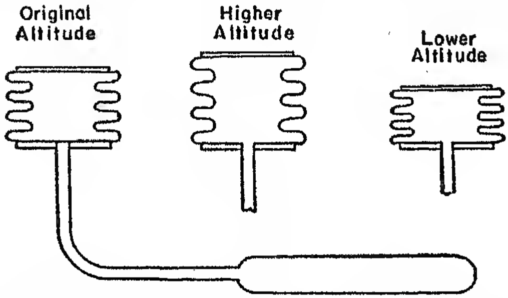

Fig. 138.—Effects of Altitude on Expansion of a Bellows.

quire setting for higher temperatures or greater pressures than those at which the control actually would operate; and for lower altitudes it would have to be set for lower temperatures or pressures than those actually realized.

Except when the apparatus is operated at an altitude greatly different from that for which adjusted the effects usually are unimportant. A low-side pressure control adjusted for an altitude of 600 feet, then taken either to 1,200 feet or to sea level, would change only about one degree with sulphur dioxide and less than a half degree of temperature with Freon-12 or with methyl chloride. Most thermal bulb controls or direct temperature

controls change only about one degree for each change of 1,000 feet in altitude, and it is necessary to allow for only this difference when making adjustments.

CHAPTER 15

TROUBLE SHOOTING

The minimum equipment required for locating the causes for faulty performance of refrigeration systems will include the following:

1. A pressure gage and a compound gage, together with fittings, connections, and wrenches allowing their attachment to any style of apparatus.

2. A service thermometer, or preferably two such thermometers so that simultaneous temperature readings may be made at two locations.

3. A voltmeter with test leads, prods and clips. The range must be sufficient to accommodate line voltages which may be encountered; a 150-volt range for 110-120 volt lines, a 300-volt range for 220-250 volt lines. Most power lines carry alternating current, for which an a-c meter is required; while a d-c meter is needed for direct current.

4. A test lamp with long leads and clips is convenient, and may be used instead of the voltmeter for many tests. A 25-watt lamp, of voltage to suit the line voltages encountered, and preferably of the "rough service" type is satisfactory.

5. An assortment of wrenches and screwdrivers to fit the various valves and adjustments.

The following tables of symptoms, causes and remedies for troubles and complaints are arranged in two groups. Tables *A* to *P* cover troubles and complaints which sometimes are evident by inspection without gage or meter tests, or which are already evident to the owner or operator of the equipment. Tables *R* to *X* cover troubles which are disclosed by making certain tests. Table headings are given in the accompanying list.

The symptoms are arranged, in general, with those of most frequent occurrence toward the beginning of the table. Not all symptoms listed can occur with all types of systems. For example, faults of an air-cooled condenser are not found with a system having a water-cooled condenser, although both kinds of faults are listed in one table. Various tests and remedies which are merely mentioned in the tables are explained in detail in other parts of this book, and may be located with the help of the index.

TROUBLE SYMPTOMS AND CAUSES

A. Compressor will not start.
B. Compressor runs continuously or too long.
C. Short cycling. Too brief or too frequent operation.
D. Cabinet too warm.
E. Cabinet warm—freezer cold.
F. Freezer too warm, but cabinet cold.
G. Cabinet too cold.
H. Odors and food spoilage or damage.
I. Frosting or sweating excessive.
J. Water inside cabinet or on floor.
K. Noisy operation.
L. Overheating at condensing unit.
M. Overload relay opens.
N. Fuses blow.
O. Electric power costs excessive.
P. Water consumption excessive.

R. Compressor inefficient.
S. Head pressure or high-side pressure too great.
T. Head pressure or high-side pressure too low.
U. Suction pressure or low-side pressure too high.
V. Suction pressure or low-side pressure too low.
W. Refrigerant flow rate insufficient.
X. Refrigeration load excessive.

A. COMPRESSOR WILL NOT START

1. **Most common causes.**
   a. Switch turned off.
   b. Cord plug making poor contact in wall receptacle.
   c. Overload cutout or relay open. See *Table M* for causes.
   d. Drive belt slipping or broken. Clean or replace belt.
2. **High-pressure cutout open.** See *Table S* for causes of high head pressure.
3. **Water failure switch open.** Remedy the cause for no water flow or insufficient water flow.
4. **Cabinet in location so cold** that temperature-type cycling control will not operate.
5. **Incorrect electric supply for driving motor.**
   a. No voltage from supply line. Check with voltmeter or test lamp, working from line connections toward cycling control as far as possible.
   b. Fuse blown. See *Table N* for causes. Do not replace the fuse without locating and remedying the cause for blowing.
   c. Line voltage excessively low. Test with voltmeter. Should not be less than 90% of normal voltage.
   d. Motor starter defective. Disconnect the equipment from the supply line, then try operating the starter by hand to determine trouble.
   e. Supply line frequency (number of cycles) does not correspond with rated frequency shown on motor nameplate. Motor must be changed to suit line.
   f. One phase open in 3-phase supply (or in 2-phase supply if used).

6. **Motor stuck.** Try rotating the motor pulley by hand; usually requires removing the belt. Should rotate with perfect freedom. Otherwise remove motor and repair or replace it with another.

7. **Compressor stuck.** Try rotating the pulley or flywheel by hand. Should rock freely through part of a turn. If turns hard or not at all, remove compressor for repairs.

   a. The compressor may have been held against rotation by liquid refrigerant or oil in the cylinder head. Turning the flywheel through two or three revolutions by hand will relieve this condition.

8. **Trouble in cycling control.** A simple test, if terminals are accessible, is to disconnect the system from the power line, connect a wire jumper between the terminals of the control, then re-connect to the line. If the motor still fails to start there are faults in the motor or in the wiring. If the motor starts with the jumper see below.

   a. Any cycling control.
   Incorrect adjustment for temperature or pressure.
   Switch contacts dirty, corroded, sticking, badly pitted.
   Mercury switch not level, adjusted wrong, tube broken.
   Broken spring, bent or binding levers, other mechanical faults.

   b. Pressure type cycling control.
   Pressure remains too low for cutting in. See *Table V* for causes.

c. Temperature control with thermal bulb. Bulb located where warmer than bellows in switch.
Leaky bellows or bellows tubing.

B. COMPRESSOR RUNS CONTINUOUSLY OR TOO LONG

1. **Excessive refrigeration load.** See *Table X* for causes.
2. **Cycling control faults.**
   a. Set for too low temperature or pressure.
   b. Electrical short circuit. Examine terminals and connections.
   c. Internal mechanical troubles.
3. **Accompanied by excessive frosting** on evaporator. See *Table I.*
4. **Thermostatic expansion valve.**
   a. Bulb loose on suction line. Let frost melt off before examining clamp.
   b. Bulb located where warmer than bellows in valve. Change location.
   c. Bulb and bellows have lost part of their charge. Bellows will feel soft when warmed up. Replace the power element.
5. **Motor starter fails to open** when cycling control opens the pilot circuit. Disconnect equipment from line, then examine starter and move it by hand. May stick due to burned contacts or to mechanical troubles which are evident upon examination.
6. **Accompanied by excessively high head pressure.** Test with pressure gage. See *Table S* for causes of high head pressure.
7. **Compressor inefficient.** See *Table R* for causes.
8. **Refrigerant flow rate insufficient.** See *Table W* for causes.

9. **Relief valve** (between discharge and low side).
   a. Dirt on seat or needle.
   b. Leaking or stuck open.

C. SHORT CYCLING

Compressor starts and stops too frequently; usually more than about six times per hour with normal refrigeration load apparently being handled. If the load is very small, and if doors seldom are opened, short running periods are normal but idle periods should be long.

1. **With any type of cycling control.**
   a. Differential set for too few degrees between cut-in and cut-out.
   b. Irregular and erratic operation with varying periods of idleness and with variable cabinet temperatures may be due to:
      Wiring loose at control terminals.
      Control mounted where jarred excessively, as near a door.
      Switch contacts pitted and burned.
      Internal levers bent or binding.
      Control springs jammed.

2. **With thermostatic (temperature) cycling control.**
   a. Adjusted for too much superheat, feeding too little refrigerant, using only part of the evaporator surface.
   b. Bulb which should be in air or liquid space to be cooled is placed too close to the evaporator where it cools too quickly.
   c. Air bulb placed directly in cold air stream coming from evaporator; cools too quickly.
   d. Bulb located where it warms up excessively or too quickly during the idle periods, thus opening the thermostatic valve.

e. Bulb is loose on the evaporator or suction line. Check the clamping while defrosted.
f. Bulb tubing touches cold surface of evaporator. Only the bulb should be in contact with the evaporator or suction line.

3. **With pressure type cycling control.**
a. Refrigerant flow rate insufficient. The limited rate of flow causes rapid lowering of suction pressure, and cutting out; then allows rapid rise of temperature and pressure, with cutting in. See *Table W* for causes.
b. Compressor inefficient; usually with head pressure or high side pressure below normal, and suction pressure or low side pressure too high or not enough vacuum. See *Table R* for causes.

4. **Evaporator faults.**
a. Excessive frost on evaporator. See *Table I* for causes.
b. Evaporator surface dirty; needs defrosting and washing.
c. Brine level too low in systems using indirect refrigeration.
d. Evaporator has accumulated an excessive quantity of oil which covers much of the internal surface and interferes with heat transfer. May result from an excessive quantity of oil in the system and too rapid circulation of oil, or from operating conditions which temporarily have allowed much of the oil to leave the compressor, thus causing a low oil level in the compressor.
e. Evaporator too small for the refrigeration load. This fault cannot exist if the system formerly operated satisfactorily with the same load.

5. **Condenser faults.**
   a. Any type of condenser.
      Condenser is fouled with dust and dirt, or has accumulated oil and grease, or has restricted air circulation for any reason.
      Condenser tubing jammed or kinked to restrict internal flow.
      Condenser too small. Does not apply if system formerly operated satisfactorily.
   b. Air-cooled condenser.
      The fan may not be operating, may have bent blades.
      Temperature of surrounding air excessively high; usually would have to be above 110° F. to affect operation seriously.
   c. Water-cooled condenser.
      Temperature of inlet water is too high. Unless temperature will return to normal within reasonable time, another supply should be found, or a connection made to a point nearer the underground water mains.
      Water flow shut off or flow unduly restricted. Examine all shutoff valves in the water lines. Check operation of the water flow regulating valve and its connections to the high-pressure side of the system.
      Clogged water passages due to bent or jammed piping, or to accumulations of scale within iron or steel piping that has been long in use.
6. **Air in the system.** Head pressure will be higher than normal for the air temperature with an air-cooled condenser, or water flow will be excessive with a water cooled condenser and regulating valve. The system requires purging of excessive air.

7. **Refrigerant control valve faults.**
   a. Any type of valve.
   Admitting too little refrigerant. May be incorrectly adjusted (with adjustable types), clogged, or stuck closed. Head pressure will be lower than normal, and suction pressure usually will be low. Hissing or bubbling may be heard at the valve.
   Admitting too much refrigerant. Usually because of dirt, corrosion, or sticking partly open. Head pressure may be lower than normal, and suction pressure will be high, or will rise quickly after compressor stops. Hissing may be heard at valve after compressor stops. Usually excessive sweating or frosting of suction line.
   b. Thermostatic expansion valve.
   Adjusted for too little refrigerant; excessive superheat.
   Bulb warmer than bellows in valve. Note action when valve body warmed with hands. Locate the valve in a more suitable position.
   Bulb and bellows have lost some of their charge. Try warming the bulb while detached and note whether refrigerant floods through evaporator. If no flooding, replace the power element.
8. **Refrigerant charge excessive.** May be knocking due to liquid slugs when compressor starts. Suction pressure higher than normal. Compressor head may be hotter than usual.
9. **Overload relay opening and closing.** An electrical overload will stop the motor and compressor when the motor temperature rises; and when the motor cools, the overload

relay will close and start the motor again. See *Table M*.

10. **High-pressure cutout opening and closing.** The motor and compressor may be started and stopped by the high-pressure cutout opening and closing the motor circuit as head pressure rises, and then falls while the compressor is stopped. See *Table S* for causes.
11. **Rotary compressor check valve,** leaky or reversed.
    Allows high-pressure gas to flow back into low side. Suction pressure will be abnormally high.
12. **Excessive refrigeration load.**
    May cause long running periods and short intervening idle periods of compressor. This is not the same as short cycling, with which both the running and idle periods are short. See *Table X*.

D. CABINET TOO WARM

1. **Air circulation restricted.**
   a. Crowding of foods or containers. Air must flow freely from evaporator through the entire space and back to the evaporator.
   b. Baffles or air flues incorrectly placed, or omitted.
   c. Evaporator too wide, too high, too long, or incorrectly placed to allow free circulation.
2. **Excessive refrigeration load.** See *Table X*.
3. **Compressor belt slipping.**
   Clean and adjust the belt. Replace if badly worn or frayed.
4. **Cycling control faults.**
   a. Adjusted for too high temperature or pressure.

b. Defective control unit, does not cut in correctly.

c. Thermostatic control bellows and bulb have lost some or all of their charge. Try warming the bulb to see whether it will cause the switch to close.

5. **Overload relay opens and closes.**
An electrical overload will allow the motor and compressor to operate only until the motor gets hot, not long enough for refrigeration. See *Table M.*

6. **Excessively high head pressure.**
High head pressure reduces the refrigerating capacity of the system. See *Table S* for causes.

7. **High-pressure cutout opens and closes.**
Excessively high head pressure will open the high-pressure cutout and stop the motor and compressor before there is sufficient refrigeration. See *Table S* for causes of high head pressure.

8. **Short cycling.**
If the compressor starts and stops too frequently, see *Table C.*

9. **Evaporator faults.**

a. Excessive accumulation of oil in evaporator, or excessive circulation of oil through system, may be preventing efficient heat transfer at the evaporator. Suction pressure will be normal or low, but evaporator will not frost as usual. Check for oil overcharge, and for lack of oil in compressor which may indicate excess in evaporator.

b. Tubular dry evaporator not level. Liquid refrigerant or oil may be trapped at low points.

c. Continuous tube type of evaporator

mounted so that refrigerant flows downward to some rows and upward to other rows, alternately. The flow should be always one way or the other through the whole evaporator.

d. Excessive frosting of evaporator. See *Table I* for causes.

10. Cabinet insulation faulty.

The insulation may have deteriorated with age, may be of poor quality, may have become water soaked because of broken sealing or openings from inside of cabinet into insulated spaces.

11. Refrigerant control valve faults.

a. Valve clogged or stuck closed, reducing the rate of refrigerant flow. The head pressure, and usually the suction pressure, will be abnormally low. Moisture freezing in the valve will stop refrigerant, allow defrosting and warming up, after which there will be refrigeration until freezing occurs again.

b. Valve adjusted for too much superheat, so that only part of the evaporator is being used.

c. Thermal bulb mounted too far back from the suction line, so that only part of the evaporator is being used.

d. Thermostatic bellows and bulb have lost part of their charge. Try warming the bulb while detached to see whether this causes flooding of refrigerant through the evaporator to the suction line.

e. The valve may be leaking or stuck open, supplying so much refrigerant that the suction pressure cannot drop to a point corresponding to the necessary low tem-

perature. Hiss may be heard at valve while compressor is idle. Excessive frost on suction line. Suction pressure high; with normal or low head pressure.

12. **Refrigerant flow rate insufficient.**
    Head pressure, and usually suction pressure, are abnormally low. See *Table W* for causes.
13. **Compressor inefficient.**
    Low head pressure and high suction pressure. See *Table R.*
14. **Multiple or two-temperature systems.**
    a. Solenoid valve remains closed or partly closed.
    b. Two-temperature pressure valve adjusted for too high pressure.
    c. Check valve reversed; prevents refrigerant flow.
15. **Condensing unit too small for load.**
    Will not be the case if system formerly operated satisfactorily with the same load conditions.

E. CABINET WARM—FREEZER COLD

1. Air circulation restricted. See paragraph 1, *Table D.*
2. Cycling control set for too high temperature or pressure.
3. Excessive frost on evaporator. See *Table I.*
4. Excessive refrigeration load. See *Table X.*
5. If compressor runs continuously or too long at one time, see *Table B.*

F. FREEZER TOO WARM, BUT CABINET COLD

1. **Incorrect food handling.**
    a. Foods too warm when placed in freezer. Should be at no higher than room temperature.

- b. In containers of glass, china, rubber, plastic, or other poor conductor of heat.
- c. Foods may contain much sugar, alcohol, or acids.
- d. Containers making poor contact with evaporator; loose, rough, separated by layer of ice.

2. **Refrigerator in cold location.**
   Compressor does not run often enough for freezing.
3. **Evaporator defrosts.**
   - a. Cycling control adjusted for too high temperature.
   - b. Differential is too great, allowing too much warm-up.
4. **Air circulation too rapid.**
   Maintains too much heat at evaporator, or too high temperature.
5. **High head pressure.** See *Table S.*
6. **High suction pressure.** See *Table U.*

G. CABINET TOO COLD

1. **Cycling control faults.**
   - a. Adjusted for too low temperature or pressure.
   - b. Thermal bulb (of temperature control) making poor contact with evaporator, or placed where temperature is higher than that to be maintained in cabinet.
   - c. With pressure-type control, leaky valves in the compressor may allow starting the compressor while the cabinet still is too cold.
2. **Compressor runs continuously or too long.** See *Table B.*
3. **Two-temperature systems.**

a. Solenoid valve sticking open, or partly open.
b. Two-temperature pressure valve set for too low pressure.

4. **Short cycling.** See *Table C.*

H. ODORS AND FOOD SPOILAGE OR DAMAGE

1. **Odors due to food.**
   a. Interior of cabinet is dirty. Should be washed periodically with a solution of one teaspoonful of baking or washing soda per quart of warm water.
   b. Old food or spilled liquids in cabinet.
   c. Odorous foods not kept in covered containers. Strong odors are absorbed by other foods, especially by butter and milk or cream, which also should be in tightly closed containers.
   d. Cabinet temperature too high for kinds of food stored.
2. **Odors due to condensation.**
   a. Drain to sewer clogged or covered, allowing water of condensation to remain inside cabinet.
   b. Openings from inside the cabinet to insulation not sealed, or sealing cover of insulation punctured, allowing soaked insulation to mold.
3. **Drain to sewer not fitted with a trap.**
   Drain preferably should be through an open funnel into a water trap.
4. **Odors from condensing unit.**
   a. Belt slipping and charred or burned.
   b. High head pressure and high temperature of compressor and motor cause odors from overheated grease and oil.

5. **Odors from insulation.**
   a. A new cabinet may contain odorous insulation or other structural materials.
   b. Vermin may have gotten into the insulation.
6. **Leakages.**
   a. Refrigerant leakage. Test for leaks in regular manner.
   b. Brine leakage from indirect refrigeration system.
7. **Refrigerator left idle** for long period with cabinet doors closed.
   Any closed space should be frequently "aired out."
8. **Foods dry out, or dehydrate.**
   a. Caused by excessively low moisture content, or humidity, of cabinet air. This often is due to using a cabinet temperature which is lower than necessary. May be helped by using a smaller differential, so that temperature does not go so low before cut-out, or by setting an expansion valve for less superheat and for using more of the evaporator.
   b. Excessively rapid air circulation removes much moisture from foods.
      Covering the foods, or partially restricting the circulation, will help.
9. **Meats become slimy.**
   a. Caused by excessively high moisture content, or humidity, of cabinet air. Cabinet temperature may be too high. May be helped by using a greater differential, providing lower temperature at intervals, and by using higher superheat with less

of the evaporator running at a lower temperature.

b. Restricted air circulation causes sliming. Rearrangement of foods may allow better circulation.

I. FROSTING OR SWEATING EXCESSIVE

1. On evaporator.

a. Cycling control set for lower temperature or pressure than necessary.

b. Air circulation restricted. See paragraph 1, *Table D.*

c. Excessive refrigeration load. See *Table X.*

d. With system intended to defrost during idle period of each cycle, incorrect adjustment of cycling control so that temperature does not rise above freezing point, or so that suction pressure does not rise to value corresponding to 32° temperature for refrigerant used.

e. Finned evaporator has fins too close together.

f. Evaporator too small, has to be operated at too low temperature.

2. On suction line.

This usually indicates that more refrigerant is being admitted to the evaporator than can be evaporated with the existing load and pressures.

a. Thermostatic expansion valve.

Adjusted to admit too much refrigerant, no superheat.

Bulb loose on evaporator or suction line. Check clamp while defrosted.

Bulb located beyond point on tubing where

frost is permissible, or located outside the refrigerated space.

Suction tubing not looped, or run so that refrigerant from one evaporator can affect temperature of bulb for another evaporator.

Valve may be defective; leaking, stuck open or partly so.

Bulb may have wrong kind of charge for refrigerant used in system.

b. Float valve.

Valve leaking, dirty, stuck open. May be flushed to correct trouble.

Low-side float evaporator not level; liquid goes into suction pipe.

Float level adjustment incorrectly set; level is too high.

Incorrect float for kind of refrigerant being used.

c. Automatic expansion valve.

Suction line frosting cannot be avoided where the load decreases below that for which the valve pressure is suitable, or where this type of valve is used to intentionally limit the refrigeration.

d. Oil trap in suction line.

Refrigerant may boil out of oil at this point and cause freezing.

e. No heat exchanger where one needed.

This may cause frosting in low-temperature systems.

f. No check valves where needed.

In some two-temperature systems check valves are required to prevent liquid refrigerant condensing in evaporators and flooding out into suction line on the following cycle.

3. **On compressor crankcase.**
   This is the extreme case of suction line frosting.
   a. Excessive flow of refrigerant.
      Liquid goes all the way back to the compressor. Check adjustment of refrigerant control valve. Suction pressure will be too high, and head pressure may be low. Hissing may be heard at a leaky valve after the compressor stops.
   b. Excess of refrigerant in system.
      May cause knocking when compressor starts, due to slugs of liquid.
      Compressor head may be abnormally hot.
   c. Excessive oil circulation.
      May affect action of the refrigerant control valve. Refrigerant may separate from oil and cause freezing at any point. Check crankcase oil level.
4. **On liquid line.**
   a. Liquid line or receiver valve partly closed.
   b. Liquid line strainer clogged at receiver or condenser.
   c. Dehydrator needs recharging or reactivating.
   d. Liquid line restricted by kinking, jamming, or internal clogging. Frost will appear at and beyond the point of restriction.

J. WATER INSIDE CABINET OR ON FLOOR

1. **Defrosting pan not emptied,** or has overflowed after too much frost accumulated between defrosting periods.
2. **Liquids spilled** in cabinet.
3. **Very moist foods** put in cabinet while warm and uncovered.

4. **Air circulation impeded** due to crowding of foods, baffles omitted or incorrectly placed, or evaporator located where it hinders circulation.
5. **Cabinet doors opened** too often when high humidity in outside air.
6. **Air leaking into cabinet** around doors due to defective gaskets, breaker strips, loose hinges, etc.
7. **Frost melting.**
   a. Suction line frosting. See *Table I.*
   b. Suction line not located over drain troughs.
   c. Evaporator extends beyond drip pan or troughs.
   d. Frost on baffles which have too little insulation or otherwise become too cold.
8. **Drain clogged,** covered, or mis-directed outside the cabinet.
9. **Air leak into insulation** from outside cabinet. Water vapor condenses in insulation and then runs out as liquid.

K. NOISY OPERATION

1. **Loose parts.**
   a. Food containers, shelves, baffles, etc., in cabinet.
   b. Refrigerant or cooling water tubing loose and vibrating. Must be firmly supported close to condensing unit. May need anti-vibration loops. Adjacent lines should be bound together with tape or clamped together for mutual support. Soft copper tubing tends to shake and vibrate less than hard temper tubing.

c. Electric conduit vibrating. A short length of flexible steel conduit may be used next to the condensing unit.

d. Compressor, condenser, receiver, motor, or other parts not tightly bolted to the condensing unit base.

2. **Fan noise.**

Blades loose or bent, enclosure loose, fan bearings loose.

3. **Foundation or support.**

a. Condensing unit does not bear evenly at all corners or all legs on the foundation, or bolts are loose in foundation.

b. Foundation not firm, or not level. Wood floors often require extra bracing underneath to carry large condensing units.

c. Shipping blocks not removed after installation of a spring-suspended condensing unit, or refrigerator with such a unit.

d. Suspension springs loose, broken, or binding.

4. **Belt noises.**

a. Squeaking noise, especially as compressor starts, often indicates a loose or badly worn belt, and more rarely a belt too tight. A loose belt may cause a slapping noise.

b. Belt pulleys not correctly aligned may cause vibration and noise.

5. **Compressor noises.**

Compressors of all types make more or less noise while in operation, such noises being much more noticeable when the compressor compartment is opened.

a. Heavy or loud pounding. Usually from liquid refrigerant or oil getting into cylinder head, due to excess charge of refrig-

erant or oil or to excess flow of refrigerant through control valve, also to incorrect valve adjustment, valve leakage, incorrect bulb location, etc.

May be due also to loose or bent pulley or flywheel. Looseness may be felt, and bending is evident upon slow rotation.

b. Vibration may be caused by a bent crankshaft and wobbling flywheel.

c. Knocking may be due to loose bearings on the crankshaft, connecting rod or eccentric. A piece of metal or of hard wood may be grasped firmly in one hand, this hand held firmly against your ear, and the other end of the piece held against various points on the compressor. Internal noises are much magnified, but cannot always be located as to position.

d. Knocking may be due to a great excess of oil in the crankcase.

e. Thumping noises may come from a defective oil pump, a clogged oil strainer, or damaged oil pump drive.

f. Sharp slapping noises may result from a loose piston.

g. Light rattling noise may result from loose piston pin bearings, being most noticeable just as the compressor is coming to a stop.

h. Clicking or chattering noises may come from defective valves or may be caused by pressures varying greatly from normal.

i. High head pressure may cause a noisy compressor. See *Table S*.

j. High-pitched squeaking usually indicates a dry or defective shaft seal.

6. Electric motor noise.

a. Grinding, rattling or pounding may mean dry or worn motor bearings, or that the motor is loose on its base.

b. Grinding or rasping noise may indicate loose bearings, armature or rotor striking the field or stator, or a bent motor shaft.

c. Sharp rattling or knocking may indicate pulleys not correctly aligned, a motor not mounted level, or excessive end play of the shaft.

d. Direct-current motors that squeak or chatter may have worn brushes or commutator, high mica, worn brushholders or brushes that do not fit the holders.

7. Valve noises.

a. Refrigerant control valves.
Lack of refrigerant or restricted flow (*Table W*) may cause noticeable hissing or bubbling noise at the valve.
Chattering usually calls for replacement of the valve, although it may be caused by misalignment of the needle or yoke, and sometimes by unusual and temporary pressure relations between high side and low side.

b. Water regulating valve.
Noise may be due to dirt holding the valve slightly open, to the valve being reversed with reference to the direction of water flow, or to mechanical defects in the valve.

c. Leaky check valve with rotary compressor may cause whistling noise.

L. OVERHEATING AT CONDENSING UNIT

1. **High head pressure.** See *Table S* for causes.
2. **Overheating of electric motor.**
   a. Motor bearings not oiled.
   b. Insufficient air circulation through and around motor.
   c. Belt too tight.
   d. Compressor binding or has excessive friction. See *Table R* which includes probable causes.
   e. Supply line voltage too low; on a-c lines.
   f. Supply frequency not same as motor rated frequency. See motor name plate.
   g. Wiring connections wrong. See connection diagram for equipment.
   h. Internal or attached starting switch defective for single-phase a-c motors. Allows starting winding to remain in circuit.
   i. Motor defects; such as internal short circuits or grounds, too little end play, etc.

M. OVERLOAD RELAY OPENS

The overload relay usually is incorporated with or is connected rather directly to the cycling control and to the leads between the power line and motor.

1. **Head pressure too high.** See *Table S* for causes.
2. **Belt too tight.**
3. **Compressor binding** or has excessive friction. See *Table R* which includes probable causes.
4. **Compressor will not start to rotate.**
   May be due to liquid refrigerant or oil in the compressor cylinder or in a rotary compressor, which may be relieved by turning the compressor a few revolutions by hand.

Otherwise examine compressor for mechanical faults.

5. **Possibly excessive power required** when first reducing the pressure and temperature. The receiver valve or the low side service valve may be partially closed to reduce the load during this period.
6. **Line voltage too high.** Should not be much more than 10 per cent above the maximum rated value.
7. **Line voltage too low.** Causes overheating of alternating-current motors.
8. **Supply line frequency** not same as that for which motor rated. Replace the motor with one of correct frequency.
9. **One phase open** in a 3-phase electric supply.
10. **Motor binding** or cannot be rotated when tried by hand. Remove the motor for repair or replacement.
11. **Relay heater element** of too little amperage capacity; overheats and opens relay with normal operating conditions or current.
12. **Internal or attached starting switch** defective for single-phase a-c motor. Allows starting winding to remain in circuit.
13. **Motor of too small power capacity** for the compressor operating with the existing refrigerating load. May be suitable for an original load which has been increased.

N. FUSES BLOW

If fuses are the only overcurrent and overload protection for the motor, the causes for blown fuses will be the same as for opening of the overload relay, listed in *Table M*. Fuses located between the supply line and overload relay (or motor starter) are intended to blow when there

is a sudden excessive current, as with a short circuit or accidental ground, but they do not prevent motor overheating due to a long continued smaller current. Overheating is prevented by the overload relay, which is caused to open as it heats due to a long continued excessive current which is not enough to blow the fuses.

1. **Fuses of too small capacity** for motor starting current.
2. **Other electrical equipment** is on the line protected by the fuses, and is causing the blowing.
3. **Short circuit or accidental ground** in wiring, control devices, or motor. The cause of blowing should be located and remedied while a test lamp or voltmeter is connected in place of one fuse. Otherwise the fuse will blow again.
4. **Heater element in overload relay** of too great amperage capacity; allowing excessive current to blow the fuses.
5. **Cycling control or motor starter** defective in operation. Examine them while the equipment is disconnected from the supply line.

O. ELECTRIC POWER COSTS EXCESSIVE

1. A commercial refrigeration plant may be entitled to a special power rate which is not being applied. See the electric service company.
2. Excessively high line voltage. Test with voltmeter.
3. Head pressure too high. See *Table S.*
4. Runs continuously or too long. See *Table B.*
5. Compressor inefficient. See *Table R.*

P. WATER CONSUMPTION EXCESSIVE

1. **Runs continuously or too long.** See *Table B*.
2. **Head pressure too high.** See *Table S*.
3. **Water supply temperature too high.** Connection should be made to a supply of lower temperature, as closer to the underground main.
4. **Water supply pressure too high.** May cause chattering of the water flow regulating valve. A pressure reducing valve may have to be installed.
5. **Water regulating valve.**
   a. Adjusted for too low head pressure, or for head pressure lower than economically obtainable with existing water supply temperature.
   b. Sticking open or leaking when shut off; due to dirt, wear, loose seat, loose needle, etc.
   c. Of too large capacity for required rate of water flow.

R. COMPRESSOR INEFFICIENT

Usually accompanied by low head pressure, high suction pressure, and the head of the compressor remaining cooler than normal.

1. **Leaky compressor** valves, piston, rings or head gasket; or leaky seals, blades, rings and housing in a rotary compressor. Apply pressure and vacuum tests as directed in earlier text pages.
2. **Rotary compressor** check valve leaking, stuck open, or reversed.
3. **Excessive friction.**
   a. Belt too tight.
   b. Lack of oil or else great excess of oil in crankcase.

c. Sprung crankshaft or drive shaft, and wobbling pulley.
d. Bearings set up too tightly.
e. Too little end play of crankshaft.

4. **Compressor runs at too low speed.**
   a. Belt slipping; loose or oily.
   b. Line supply voltage too low. Test while the motor is running.
   c. Incorrect pulley ratio; usually too small motor pulley.
   d. Motor too small for the load, or defective.

S. HEAD PRESSURE OR HIGH-SIDE PRESSURE TOO GREAT

Usually accompanied by compressor head abnormally hot, driving motor running rather hot, and possibly by high suction pressure.

1. **Air in system; requires purging.**
2. **Refrigerant charge too great.** Condenser tubing filled with liquid above normal level, reducing the cooling area and requiring higher pressure.
3. **With any type of condenser.**
   a. Refrigerant passages clogged, tubing jammed, or passages otherwise restricted.
   b. Condenser of too small capacity.
4. **With air-cooled condenser.**
   a. Surface dirty or dusty; lessens heat transfer.
   b. Air circulation impeded in any way.
   c. Fan not running, blades twisted, enclosure not in place.
   d. Surrounding air temperature excessively high.
5. **With water-cooled condenser.**
   a. Inlet water too warm.

b. Water shut off or insufficient flow rate for any reason.
c. Water regulating valve adjusted for too little flow, allowing high head pressure.
d. Water spaces in condenser not vented of air, causing decreased heat transfer area.

6. **Discharge service valve not fully open.**

7. **Restricted liquid line.**
 a. Receiver valve not fully open.
 b. High-side float valve not opening.

T. HEAD PRESSURE OR HIGH-SIDE PRESSURE TOO LOW

1. **Heat transfer retarded.**
 a. Evaporator excessively frosted. May be due to causes in *Table I.*
 b. Evaporator surface dirty or otherwise covered.

2. **Refrigerant flow rate insufficient.** Suction pressure usually low. See *Table W.*

3. **Leaky discharge valve** in compressor.

4. **High-side float valve leaking** or remains open due to dirt or mechanical defect in valve.

5. **Condensing unit in excessively cold location.**

6. **Water-cooled condenser.**
 a. Water supply too cold.
 b. Water flow too great or not regulated.
 c. Water regulating valve adjusted for maintaining low head pressure, or for excessive rate of water flow.

7. **Compressor inefficient.** See *Table R* for causes.

U. SUCTION PRESSURE OR LOW-SIDE PRESSURE TOO HIGH

1. **Excessive refrigeration load.** See *Table X* for causes.
2. **Compressor running too slowly.** Causes are listed in *Table R.*
3. **Leaky suction valve or slight leak at discharge valve in compressor.** Rotary compressor blade clearance excessive, or rotor worn.
4. **Excessive flow of refrigerant.**
   Head pressure may be low or normal. Usually accompanied by sweating or frosting of suction line and possibly of compressor crankcase.
   a. Refrigerant control valve adjusted to admit too much refrigerant.
   b. Refrigerant control valve leaking or sticking open due to dirt or a mechanical defect. Try flushing the valve.
   c. Thermostatic expansion valve bulb loose. Check clamp while line not frosted.
5. **Pressure type cycling control** adjusted for too high pressure.
6. **Short cycling.** See *Table C* for causes.
7. **Condensing unit of too small capacity** for evaporator and load.

V. SUCTION PRESSURE OR LOW-SIDE PRESSURE TOO LOW

1. Refrigerant flow rate insufficient. See *Table W* for causes.
2. Cycling control adjusted for too low temperature or pressure.
3. Condensing unit in excessively cold location.
4. High-side float valve does not open. Float punctured, or for other reason fails to rise.

5. Excessive circulation of oil through system. Check oil level in compressor.

W. REFRIGERANT FLOW RATE INSUFFICIENT

Symptoms and tests.

Head pressure low. Suction pressure usually low. Compressor head temperature lower than normal.

Hissing or bubbling sound at refrigerant control valve as vapor goes through with liquid. Small changes of valve adjustment cause less than the usual changes of evaporator and suction line frost. Temporary warming of a thermostatic expansion valve bulb has little effect on flooding of refrigerant through evaporator and lowering of suction line temperature.

Frosting or heavy sweating occurs at and just beyond a point at which the flow is unduly restricted.

1. **Liquid or suction line tubing.**
   a. Kinked, jammed, clogged internally.
   b. Diameter too small or length too great for the load.
2. **Lack of refrigerant in system.**
   Head pressure low. Suction pressure low, and rises more slowly than usual after compressor stops. Hissing or bubbling sounds heard at refrigerant control valve while compressor runs. Check system for leaks.
3. **Valves wholly or partially closed.**
   a. Receiver valve or any liquid line valve.
   b. Either the suction or discharge service valves.
   c. Manifold shutoff valve in multiple evaporator system.
   d. Solenoid valve. Listen for sound of opera-

tion at the valve while operating the thermostat switch by warming the thermostat temporarily.

4. **Any type of refrigerant control valve.**
   a. Adjustable type set for too little refrigerant flow.
   b. Clogged or stuck closed. May be lightly tapped or jarred, or may try flushing the valve.
   c. Water frozen in valve. Refrigerant is intermittent; continuing each time only until water freezes, then stopping until system defrosts.
   d. Valve seat opening or orifice too small, too little capacity.
5. **Low-side float valve.**
   a. Header valves wholly or partially closed.
   b. Float set too high to allow opening of valve.
6. **High-side float valve.**
   Fails to open because of punctured float or other cause.
7. **Thermostatic expansion valve.**
   a. Bulb warmer than bellows in valve. Warming the valve with your hands may then relieve the condition temporarily.
   b. Bulb charged for other than the kind of refrigerant being used in the system. The valve cannot be satisfactorily adjusted.
8. **Compressor inefficient.** See *Table R.*
9. **Strainers clogged.**
   Check separate strainers in liquid and suction lines, also strainers built into refrigerant control valves.
10. **Dehydrator causing restriction.**
    Requires recharging or reactivating.
11. **Oil traps.**
    In suction lines of multiple system.

12. **Evaporator too high above condensing unit.** Requires excessive lift of refrigerant liquid. Condition relieved by operating the system at higher condensing pressure or higher head pressure through adjustment of water regulating valve or slight reduction of air circulation through condenser.

X. REFRIGERATION LOAD EXCESSIVE

Head pressure usually is normal, but suction pressure is abnormally high.

1. **Foods.**
   Hot foods or steaming foods, or liquids, placed in cabinet. They should first be allowed to cool to room temperature.
2. **Surrounding air temperature.**
   a. Room temperature very high; usually 110° F. or more.
   b. Refrigerator located near heating element such as radiator, or in sunlight, etc.
3. **Doors.**
   a. Doors opened oftener and for longer times than necessary.
   b. Doors loose on hinges or latches; have broken or flattened gaskets. Tightness or looseness of fit may be checked by inserting strip of paper, closing the door on it, then trying to pull out the strip.
4. **Insulation.**
   a. May have become water soaked because of broken covering or sealing.
   b. Poor quality which has packed down or has separated into lumps.
   c. Breaker strips may be loose or poorly fitted.

5. **System capacity deficient.**
   a. Evaporator too small for the load at desirable temperatures.
   b. Condensing unit too small for the evaporator and load.

CHAPTER 16

ABSORPTION REFRIGERATION

In the absorption method of refrigeration the refrigerant is ammonia. At one point in the cycle vaporized ammonia is absorbed by water, is carried through part of the system as an ammonia and water solution, and at a later point in the cycle the ammonia is separated from the water. The separated ammonia gas is condensed to liquid ammonia, then is evaporated to absorb heat, and the resulting ammonia vapor is again absorbed by the water.

The elementary principle of absorption refrigeration is illustrated by Fig. 139. In the boiler is a solution of ammonia in water. The solution is heated by a flame or other means. The higher the temperature of such a solution the less ammonia it will retain. Consequently, heat drives ammonia gas out of the water in the boiler. The hot gas passes to a condenser, of either the water-cooled or air-cooled type, in which heat is removed and the gas condensed to liquefied ammonia. The liquid ammonia goes through a liquid trap to the evaporator, where the liquid evaporates as it absorbs heat from the surroundings. The ammonia vapor passes into cool water in the absorber and enters into solution with the water. The resulting solution, which is strong in ammonia, passes into the boiler. Separation of ammonia from water in the boiler leaves a weak solution, which returns to the absorber.

A practical absorption system consists of the parts shown by Fig. 140. Here the boiler is called the generator, which is the usual name for the device in which ammonia gas is separated from the water. The generator solution is heated by a steam coil rather than by a flame. The absorber, in which am-

monia vapor is absorbed into the water, is cooled by a cold water coil. The lower the temperature of the water the greater is the quantity of ammonia absorbed into a given volume of liquid. The condenser and evaporator serve the same functions as in any other refrigeration system. Condensed ammonia passes into the evaporator through an expansion valve. The vaporized ammonia goes to the absorber.

Strong solution from the absorber is delivered by a pump to the analyzer. In the analyzer there is a

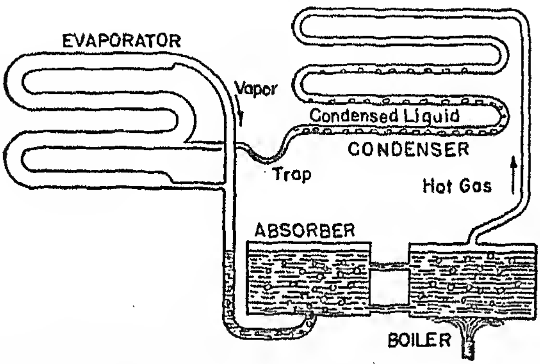

Fig. 139.—The Elementary Principle of Absorption Refrigeration.

flow of the ammonia solution over a series of plates which are in the gas-filled space above the liquid in the generator. Much of the ammonia leaves the water in the analyzer. The remainder is driven out by heat in the generator. The weak solution, which has lost most of its ammonia, returns to the absorber through a pressure regulating valve.

Ammonia gas from the generator and analyzer still has mixed with it some water vapor. The mixture of gas and water vapor passes into the rectifier,

where the water vapor condenses to liquid water. The condensed water has in solution a certain quantity of ammonia. This solution returns from the bottom of the rectifier to the analyzer. From the rectifier we have hot ammonia gas, practically free from water, passing to the condenser.

In the system shown by Fig. 140 there is a high side or high-pressure side of the cycle extending from the pump through the analyzer, generator, rec-

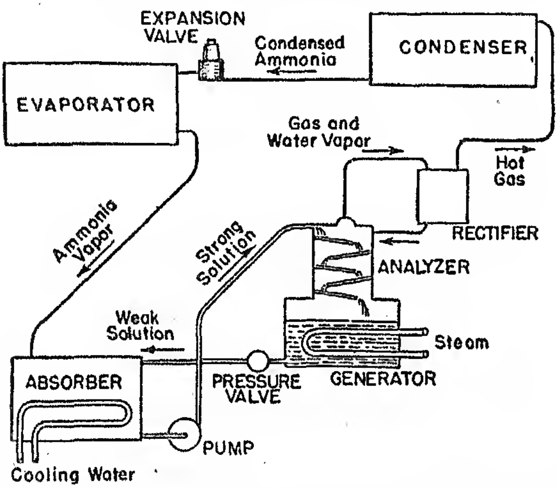

Fig. 140.—A Practical Absorption System Employing a Circulating Pump and Pressure Valves.

tifier and condenser to the expansion valve at one point and to the pressure valve at another point. There is a low side or low-pressure side extending from the expansion valve through the evaporator and absorber to the pump and the pressure valve. The compressor of a compression system is replaced in the absorption system by the absorber, the generator, the analyzer, the rectifier, the pressure valve

and the circulating pump. The condenser, the expansion valve and the evaporator are similar in both methods of refrigeration.

The Electrolux Absorption System.—The Electrolux domestic refrigerator employs an ammonia absorption system in which there is no pump and no valves of any kind. Fig. 141 is a schematic diagram of the principal parts of this system. Again we have the condenser, the evaporator, the absorber, the generator, the analyzer and the rectifier, which perform the same general functions as in the system previously described. It is in the method of ammonia circulation and of maintaining necessary pressure differences that the Electrolux system differs from other absorption methods.

Before proceeding to an explanation of the manner in which this system operates it will be well to examine some of the features illustrated by the complete diagram of Fig. 141. The evaporator consists of two sections. The upper section cools the entire food cabinet, while the lower section cools the freezing compartment. The condenser consists of two sections. Most of the hot ammonia gas is condensed to liquid in the lower section and passes to the evaporator through a liquid trap. Gas which is not condensed in the lower section goes into the upper section, where it is condensed and delivered to the evaporator through a second liquid trap. The pressure chamber contains hydrogen gas which performs an important function in circulating ammonia vapor from the evaporator to the absorber, and which also maintains pressure differences which allow condensation and evaporation.

In Fig. 141 there are two heat exchangers, one for gas and the other for liquid. In the spaces within the evaporator, the heat exchanger for gas, and the absorber there is hydrogen gas in addition

to the ammonia liquid and vapor. Vaporized ammonia mixed with hydrogen forms a relatively cool and heavy combination which leaves the top of the

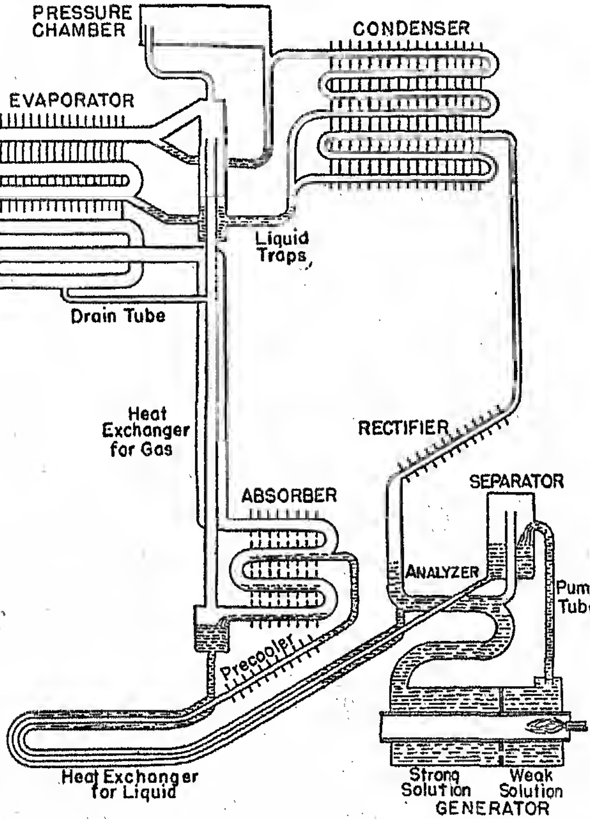

Fig. 141.—The Principal Parts of the Electrolux Air-cooled Absorption System of Refrigeration.

evaporator and flows downward through the central tube of the gas heat exchanger to the bottom of the absorber. Water flowing through the absorber takes

the ammonia into solution and leaves the hydrogen, which passes upward through the outer tubing of the heat exchanger into the lower part of the evaporator. The hydrogen rising through the outer tubing loses some of its heat to the cold mixture in the inner tubing of the heat exchanger, and thus the hydrogen is cooled before it reenters the evaporator.

Hot weak solution from the generator passes through the central tubing of the heat exchanger for liquid in going to the absorber. Relatively cool strong solution from the absorber passes through the outer tubing of this heat exchanger in going to the analyzer. The hot weak solution loses heat in the exchanger and enters the absorber at relatively low temperature, which enables it to take up more ammonia than were the temperature to remain high. The solution flowing to the analyzer and generator is warmed by its gain of heat in the exchanger, and so does not have to have so much heat added in the generator in order that its temperature may be high enough for efficient discharge of ammonia gas from this solution. There is a precooler section of finned tubing between the heat exchanger for liquid and the absorber, and the absorber itself has finned tubing to assist in lowering the temperature of solution entering the absorber and flowing through it.

Fig. 142 shows the ammonia circulation in the Electrolux system, with most of the tubing represented by single lines. Arrows with identifying letters indicate the form in which the ammonia exists at various points, also the direction of travel. In the right-hand side of the generator, wherein maximum heat is applied by the gas flame, we have weak solution. Separation of ammonia forms bubbles of gas which, together with liquid, rise rather forcibly through the pump tube to carry solution into the separator where the liquid goes to the bottom and

passes through the heat exchanger for liquid into the absorber.

Strong solution coming from the absorber to the generator by way of the heat exchanger flows downward through the analyzer. Ammonia gas driven out of solution by heat in the generator rises through the analyzer and goes to the condenser. Ammonia gas from the separator goes through part of the analyzer and passes to the condenser along with the

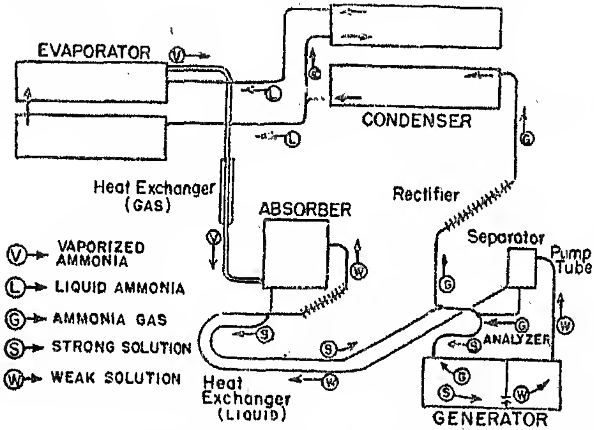

Fig. 142.—The Paths Followed by Ammonia in Its Various Forms and Solutions.

gas which has come from the left-hand end of the generator. Any water vapor in the gas condenses in the rectifier and flows back to the analyzer. Between the two sections of the generator is a partition with an opening through which solution passes from left to right in the diagram.

Ammonia gas is condensed to liquid in the two parts of the condenser. The liquid goes to the evaporator, is vaporized, and goes to the absorber through the heat exchanger for gas. Cool weak solu-

tion enters the upper part of the absorber and flows downward as it takes up more and more ammonia vapor until, at the bottom of the absorber, we have strong solution which goes back to the generator by way of the liquid heat exchanger and the analyzer. Thus ammonia passes around and around the system in the direction indicated by arrows in Fig. 142.

Fig. 143 shows the paths followed by the weak solution and the strong solution. After the weak solution has passed through the absorber it has

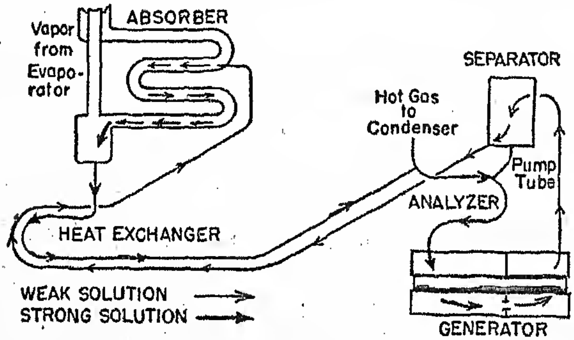

Fig. 143.—The Circulation System for Weak Solution and Strong Solution.

taken up enough additional ammonia to form strong solution. The strong solution flows, as shown by heavy arrows, through the heat exchanger and analyzer to the generator. Ammonia is separated in the generator, so that the liquid becomes weak solution. The weak solution is carried upward by gas bubbles rising in the pump tube, goes through the separator, and back through the heat exchanger to the absorber.

The Hydrogen Cycle.—The flow of hydrogen gas through the evaporator, the absorber, and the connecting heat exchanger is shown in Fig. 144 by full-

line arrows. Flow of evaporated ammonia vapor is shown by broken-line arrows. As ammonia vaporizes in the evaporator the vapor mixes with the hydrogen, not to form any chemical compound, but merely to form a physical mixture of the two. The mixture of ammonia and hydrogen is much heavier than hydrogen alone. This heavy mixture falls because of its weight through the central tube of the heat ex-

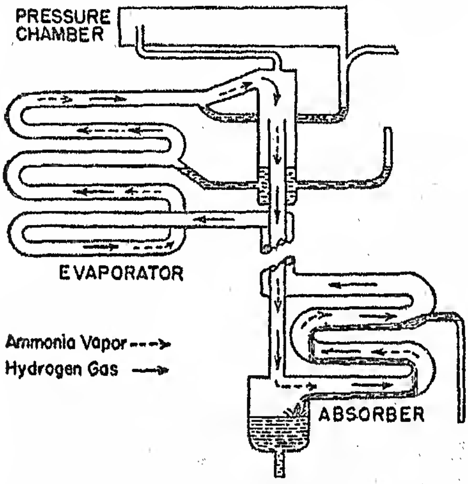

Fig. 144.—The Hydrogen Circulation System Through the Evaporator and Absorber.

changer and enters the bottom of the absorber. Passing upward through the absorber, the mixture of ammonia and hydrogen meets the downward flowing weak solution. The affinity of water for ammonia is far greater than that of hydrogen, so the ammonia leaves its mixture with hydrogen and goes into solution with the water. The remaining hydrogen, which is the lightest of all gases, rises through the outer tube of the heat exchanger, enters the

lower part of the evaporator, and rises through the evaporator to again mix with ammonia vapor. The difference between weights of the ammonia-hydrogen mixture and the hydrogen which has been practically freed of ammonia is great enough to maintain circulation in the directions shown by Fig. 144.

In addition to carrying ammonia vapor from the evaporator to the absorber, hydrogen acts to lower the ammonia pressure in the evaporator far enough below the ammonia pressure in the condenser to permit evaporation of ammonia in the evaporator. The basic reason for the action is illustrated by Fig. 145

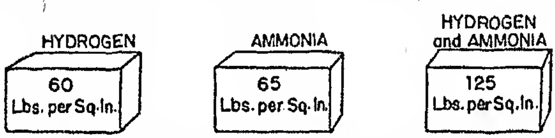

Fig. 145.—The Total Pressure of a Gas Mixture Is Equal to the Sum of the Partial Pressures of the Separate Gases.

where there are three containers, all of exactly the same volume and all assumed to be at the same temperature. One container is filled with hydrogen and another with ammonia vapor or gas. Into the third container have been placed the volumes of the two gases which were in the other two containers. The pressure of the two gases, or the pressure of their mixture is exactly the sum of their separate pressures. In any mixture of gases which have no chemical action on one another the total pressure is equal to the sum of the pressures which the separate gases would exert were each gas to occupy by itself the same total volume, assuming that the temperature is unchanged. This is Dalton's law for partial pressures.

In the upper part of Fig. 146 are shown two con-

tainers representing the evaporator and condenser of the absorption system. In the evaporator is hydrogen gas at a pressure of 60 pounds per square inch, and in the condenser is ammonia at a pressure of 125 pounds per square inch, approximately the pressure for condensation at 75° F. In the lower part of Fig. 146 the evaporator and condenser have been connected together by a loop of tubing, with the only separation a small quantity of liquid ammonia in the loop. The total pressures in the evaporator and condenser must be practically the same. When ammonia from the condenser evaporates into the space of the evaporator the ammonia will mix with the

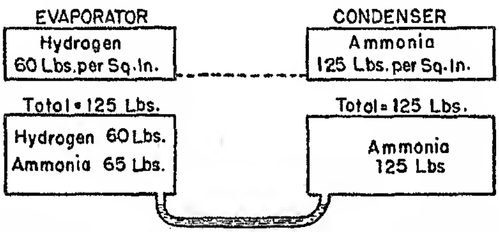

Fig. 146.—With Equal Total Pressures in Condenser and Evaporator There Is Lower Vapor Pressure for Ammonia in the Evaporator.

hydrogen. But hydrogen pressure in the evaporator already is 60 pounds, and since the total pressure will become only 125 pounds (to equal the condenser pressure), the partial pressure of the ammonia in the evaporator can be equal only to 125 pounds minus 60 pounds, or 65 pounds per square inch. This is the approximate pressure for evaporation of ammonia at a temperature of 44° F.

Although the total pressure in the evaporator is practically the same as total pressure in the condenser, the vapor pressure of ammonia in the evaporator is well below the vapor pressure of ammonia

in the condenser. The difference, for the evaporator, is made up by hydrogen pressure. With pressures which are practically equal throughout the entire system it becomes possible to evaporate ammonia to remove heat from things around the evaporator, while condensing ammonia as heat is removed from the ammonia gas in the condenser.

If the refrigeration load in the cabinet or in the freezer is increased there is a more rapid evaporation of ammonia to take up the extra heat, and ammonia enters the evaporator from the condenser more rapidly—just as in any other refrigeration system. Additional ammonia vapor increases the rate of circulation between evaporator and absorber to more rapidly strengthen the strong solution flowing from absorber to generator. More ammonia is released from the stronger solution going into the generator, so more ammonia gas is fed to the condenser, and more liquid ammonia becomes available for the evaporator.

The pressure chamber, connected between condenser, evaporator and absorber as in Fig. 147, contains only hydrogen gas when operating temperature and load are average. If the cooling load is increased, or if room temperature rises, the extra gas coming into the condenser from the generator is more than can be condensed at the then existing temperature. The result is that some ammonia gas is forced into the pressure chamber. The relatively heavy ammonia gas displaces light hydrogen gas, and the displaced hydrogen is forced into the hydrogen circulation system which includes the evaporator and absorber. The pressure in the whole system thus is raised to a value which allows condensation of the extra gas in the condenser.

If the refrigeration load decreases, or if room temperature drops, any ammonia in the pressure cham-

ber condenses and passes to the liquid ammonia supply. The resulting reduction of pressure in the pressure chamber allows hydrogen to flow into this chamber from the evaporator-absorber system. Thus the pressure in the circulating system is reduced to a value suitable for the existing load or temperature. The hydrogen supply in the pressure chamber is used to automatically vary the internal pressure of

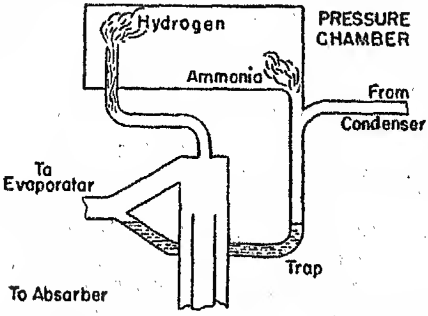

Fig. 147.—Hydrogen from the Pressure Chamber Varies the Operating Pressure with Changes of Load and Room Temperature.

the system to correspond with usual variations of load and room temperature.

The two liquid traps which are between the sections of the condenser and the evaporator make liquid seals which prevent hydrogen passing from the evaporator-absorber system directly to the condenser. There is no need for effective pressure seals between evaporator and condenser because of the fact that total pressures are practically alike in these two units.

Absorption System Operation.—Troubles with the evaporator, freezer and cabinet of the absorption system are no different from similar ones in a compression system, and the remedies are the same.

There must not be excessive frosting of the evaporator, and air circulation in the cabinet must not be unduly impeded.

The finned air-cooling surfaces of the condenser, absorber, rectifier and precooler must be kept reasonably free from dirt and dust in order that heat from these parts may pass freely to surrounding circulating air. Air circulation must not be unduly impeded. The action within the absorption system depends to a considerable extent on differences between solution temperatures at the absorber and the generator, since it is low temperature that allows ammonia pickup in the absorber, and high temperature that insures discharge of ammonia gas in the generator system. Insufficient temperature differences allow weak solution to come to the absorber at too high temperature and with too much absorbed ammonia, and prevent strong solution from having a full charge of ammonia as it goes to the generator.

The system consists largely of tubing lines and of units made from tubing, all of which is completely closed or sealed while in operation. There is a uniform high pressure (total pressure) in all parts of the system. Since the internal pressure is far above atmospheric pressure, leaks will be outward and they will carry ammonia out of the system. Leaks may be detected with the usual method of burning sulphur sticks or candles near the suspected location. Ammonia with the sulphur fumes produces a white fog or fumes of ammonium sulphite. Leaks of ammonia may be detected also by the use of moistened litmus paper, which turns blue when reached by ammonia.

If more than usual heat is required from the gas burner it usually indicates that soot or scale is being deposited in the flue passage because of incorrect gas and air mixture in the burner. The flame should

be adjusted to burn with a clean blue color, from which there is a minimum deposit to prevent heat transfer into the solution within the generator.

Design and arrangement of the elements varies somewhat with the type and model of refrigerator. As shown by Fig. 148, the absorber may be a cylindrical tank containing baffled internal passages and with cooling supplied by an external coil containing methyl chloride. The methyl chloride is heated and evaporated in this coil, then flows through an auxil-

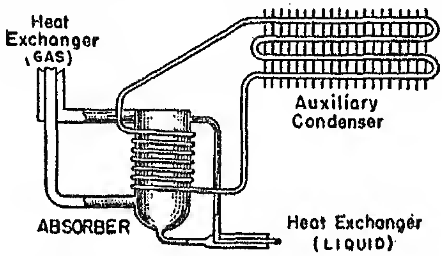

Fig. 148.—An Auxiliary Methyl Chloride System May Be Used to Cool the Absorber.

iary condenser where it is cooled and from which it is returned to the coil around the absorber. The methyl chloride condenser is mounted just below the ammonia condenser.

In addition to the finned tube rectifier there may be an additional rectifier between the condenser and evaporator. This second rectifier is made like a heat exchanger, with hot gas flowing through a central tube to the condenser, and with condensed liquid flowing through the outer shell on its way to the evaporator. The pressure chamber for hydrogen supply may be a vertically mounted cylinder connected by tubing lines between the bottom of the absorber and the top of the evaporator-condenser connection. The analyzer may be in the form of a

vertical cylinder, again with internal and external concentric passages. Weak solution flows downward through the internal passage and goes through the liquid heat exchanger to the absorber. Variations in design and arrangement do not affect the principles of operation, which are as previously explained in all the systems which employ air cooling.

Water cooled absorption refrigerators employ a double-tube condenser which carries cooling water. The cooling water flows also around a cylindrical absorber, as does the methyl chloride tubing coil in Fig. 148. Except for the different means of removing heat from the system the operation of the water-cooled models follows the same general principles as do the air-cooled types.

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